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ABBREVIATIONS.—P = Paper ; D = Discussion ; I = Illustrated.
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GEORGE W. PERCY

President, Technical Society of the Pacific Coast.

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HYDRAULIC EXCAVATION.

BY LATHAM ANDERSON, MEMBER ENGINEERS' CLUB OF CINCINNATI.

[Read before the Club, October 18, 1900.*]

THE origin of hydraulic mining is recorded as follows by an eminent authority, Mr. Charles Waldeyer, of California, and published in the report of Dr. Rossiter W. Raymond, United States Commissioner of Mining Statistics, 1873. Page 390 *et seq.*:

"The origin of hydraulic mining dates back as far as the spring of 1852, . . . when a miner, whose name is forgotten, put up a novel machine on his claim at Yankee Jim, in Placer county, Cal. This machine was very simple. From a small ditch on the hillside, a flume was built towards the ravine, where the mine was opened; the flume gained height above the ground as the ravine was approached, until finally a 'head' or vertical height of 40 feet was reached. At this point the water was discharged into a barrel, from the bottom of which depended a hose, about 6 inches in diameter, made of common cowhide, and ending in a tin tube about 4 feet long, the latter tapering down to a final opening or nozzle of 1 inch.

"This was the first hydraulic apparatus in California. Simple in design, dwarfish in size, yet destined to grow out of its insignificance into a giant powerful enough to remove mountains from their foundations."

Within three decades after the conception of that germ of the giant the topography of two antipodal continents has been profoundly modified, in large areas, by hydraulic mining. In California alone countless millions of cubic yards of detritus, torn from their primordial beds, have been transported from the mountains to the ocean, an average "haul" of more than 100 miles, or have been dropped on the way in the main river beds and the Bay of San Francisco. Many miles of the abyssmal canyons of

*Manuscript received December 31, 1900.—Secretary, Ass'n of Eng. Socs.

the Sierras have been filled a hundred feet and more in depth by the heavier parts of the tailings.

When one is first brought to face these stupendous results, he finds it difficult to accept facts so at variance with previous human experience. But the main facts are incontrovertible, having been recorded in years of litigation and legislation concerning the struggle for existence between the farmers and the miners. For the filling of the river beds with tailings so increased the destructive effects of floods as to damage or ruin whole districts of farming country, and the shoaling up of large areas in the bay had so seriously affected navigation therein that these two interests combined and organized to demand the abolition of hydraulic mining. The outcome was a Waterloo to the great hydraulic mining companies. Nothing could more strongly emphasize the vastness of these deposits and their resulting damages than that verdict of the courts and legislature. It is still further accentuated by the fact that these findings and laws were possible in California,—the child of mining, and especially of gravel mining,—which has produced more than three-fourths of all the gold output of the State.

The extent of these mining operations may be further illustrated by a glance at two of the large hydraulic mines as types of the class,—viz, the North Bloomfield, in Nevada county, Cal., and the Spring Valley, at Cherokee, Butte county. The capital invested in the North Bloomfield was $2,500,000. To gain outlet for the tailings into the nearest canyon, a tunnel 7 by 9 feet, 6900 feet long, had to be cut through solid rock. The sluice line was over 2 miles in length and 6 feet wide. The "bank" or auriferous gravel deposit was 400 feet deep and 600 feet wide, the company owning a mile and a half in length of this deposit. A 6-inch giant was used under a 500-foot head delivering 32.8 second feet of water and developing nearly 1690 horse power; and a 7-inch nozzle under a 250-foot head, delivering 31.54 second feet and developing about 1560 horse power. From 15,000 to 18,000 cubic yards of gravel were washed away each day of twenty-four hours.

The Spring Valley bank was about 400 feet in height. The bed rock tunnel was much shorter, but to obtain a dumping ground the company had to purchase over 700 acres of valuable farm land. At the time of the writer's visit in 1882, they had buried this land 12 feet deep with tailings, were expecting to add three feet to this depth, and still would be under the necessity of buying more land.

At the Dardenelles Mine 10-inch nozzles, under heavy pressure, are said to have been used.

All the data concerning the three above-named mines are given from memory, the writer not having any records at hand for verification.

It may seem superfluous to rehearse before an audience of engineers so many facts concerning hydraulic excavation, which have become stale history. The only purpose of the recital is to emphasize the strangeness of this strange freak in economic history, that in this century, pre-eminent for discoveries and appliances in the mechanical arts, so little has been done towards adopting, in general engineering practice, this most economical of all methods of earth removal. It is still more singular that it has not been generally adopted in the mining of other ores than gold, especially in winning limonite iron from its clay beds on the flanks of hills to which, in the writer's opinion, it is better adapted than even to gold mining.

But this is only in passing, as mining is not within the scope of this paper.

For the purposes of this discussion, there are three different processes employed in hydraulic excavation,—viz:

First. The sluice (sometimes called the "ground-sluice").

Second. The "giant."

Third. The "boom."

Under certain conditions all may be used to advantage by the general practitioner.

The second is, in the opinion of the writer, more generally applicable, and more powerful and economical in the class of works herein contemplated.

The sluice is best adapted to shallow deposits, where the banks would not be high enough to cause danger from caves. It consists simply of a line of boxes laid along the bottom of an open cut through the deposit to be moved. The material is loosened by the pick or plow, and shoveled by hand or dumped from wheelbarrows into the stream running through the boxes, at the lower end of which it is discharged upon the dump. Of course the more copious the supply of water, and the rate of fall in the boxes, the greater their carrying power and the economy of the process.

The boom consists of a temporary dam behind which the water supply is allowed to accumulate till a sufficient amount is stored, when the water is let out in a rush by suddenly opening large flood gates. The wave or torrent thus produced is directed against the foot of the bank to be removed. It is said that the boom has seldom been used outside of Colorado; but its advo-

cates there claim that it is one of the most economical methods of hydraulic excavation where the supply of water is either very abundant or very scarce.

The writer has had no experience with the hydraulic boom, and only quotes from other writers on the subject.

The following table is quoted from Van Wagenen's "Manual of Hydraulic Mining" (D. Van Nostrand Company), page 20, to illustrate the comparative efficiency of primitive hand work and the three types of hydraulic mining above enumerated.

The two materials assumed as a basis of comparison are ordinary loose and cemented gravels. Of course only an approximate and general average is attempted in such tables. According to the writer's experience, while very soft and friable clay will cut and wash away more rapidly than any gravel, the average compact clay bank will come between the two enumerated gravels in rate of working, being closer to the loose gravel.

TABLE.

	Ordinary.	Cemented.
By the pan.	1 cu. yd	¾ cu. yd.
" " rocker.	2 " yds	2 " yds.
" " long ton.	5 to 6 " "	3 to 5 " "
" " sluice.	10 to 20 " "	6 to 12 " "
" " hydraulic.	100 to 1000 " "	100 to 1000 " "
" " boom.	unlimited.	unlimited.

The table shows the number of cubic yards of dirt which may be washed per day of ten hours per man, in the first two cases each man working alone, and in the last four in pairs or economically arranged gangs.

The likelihood that the boom will ever be indicated as a sole means of excavation in general practice is so remote that the device is not worthy of consideration here, but it may, in rare instances, be a useful auxiliary to the giant. It is also frequently beneficial to increase the carrying capacity of an hydraulic sluice line by turning into its head an auxiliary natural stream without head, or from a lower source than that supplying the giant.

Mr. Waldeyer's paper, above quoted, contains a lucid description of hydraulic mining, and, notwithstanding the fact that it was written more than a quarter of a century ago, the reader may gain a clear impression of all the essential features of the process which are germane to this discussion.

But a word of caution is demanded here to the reader who consults text-books on hydraulic gold mining for information as

to the serviceability of the hydraulic for general purposes. We must keep in mind that the sole aim of the miner is to save gold, and as much gold as possible, consistent, of course, with economy. To this end, it is always necessary to restrict the amount of gravel carried by the boxes in order to increase the yield of gold.

(It goes without saying that all the mere gold-saving improvements and appliances of the miner are foreign to the topic in hand.) The maximum discharge of the boxes occurs when the velocity of the current is greatest and the water is most charged with mud, but the clearer the water and the slower the current the more readily will the fine gold settle to the bottom of the boxes and be caught by the quicksilver. Hence the necessity of restricting the discharge, in order to increase the amount of gold

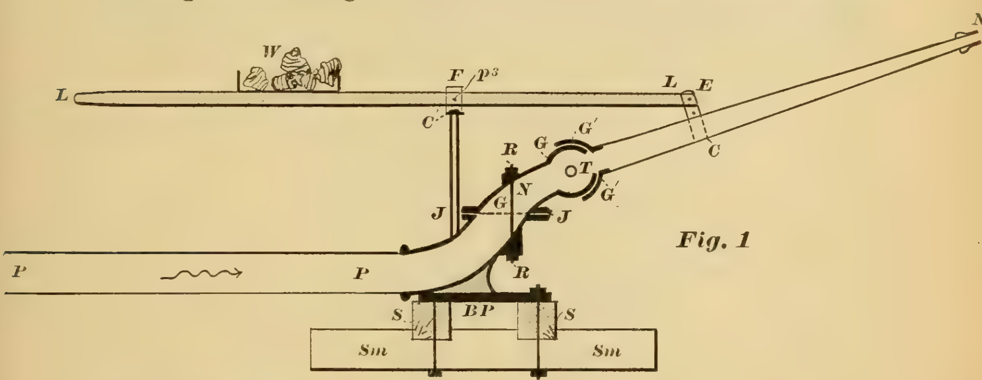


Fig. 1

saved, and whence it follows that statistics from gold-mining practice must invariably underestimate the capacity of the giant as a labor-saving device.

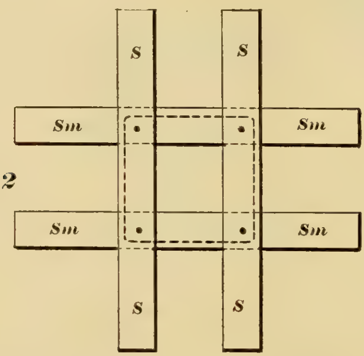
To recapitulate the conditions essential to economical hydraulic excavation, they are: the greater the volume of water, the head and the fall in the sluice line, the higher the bank (*i.e.*, the deeper the cut), and the more available the dumping ground, the greater the economy.

As all of these must be self-evident to every engineer, except possibly that of the height of the bank, we will refer to that at length further on.

It is now in order to outline the process of opening and working an hydraulic mine. From the great storage reservoir in the Sierras, fifty or one hundred miles distant, a ditch conveys the water to the service or distributing reservoir, which is on the nearest hill to the "cut" which will give the required "head" or pressure. From the distributing reservoir the water is conveyed to the workings in a riveted sheet iron pipe, in 16-foot lengths, which

are jointed stovepipe fashion. To the lower end of the pipe line P, Fig. 1, is strongly attached the giant. A longitudinal section of one of the smaller sizes is shown in Fig. 1. This consists of a pipe about 9 feet long, attached at its lower end to a cast iron globular casing or jacket G^1, inclosing the minor globe G. Attached to the outer surface of G are the trunnions T, whose horizontal axis passes through the center of the spherical surfaces G and G^1. The trunnions pass outwardly through collars in the casing G^1. This arrangement permits ample upward and downward movement of the pipe. The outer end of the pipe is provided with a screw joint, so that nozzles N of different aperture may be attached. There is a horizontal joint J between the lower extension of the globe, called the "goose neck" (GN), and the heavy bedplate BP. Of course all joints and bolt holes

Fig. 2



must be packed water-tight. (The joint J is tightened by the rod R passing down through the goose neck and bedplate.) Horizontal and vertical motion may be imparted to the pipe, simultaneously, if desired, by the lever L, a piece of scantling attached, at its front end E, to the pipe by the collar strap C, and to the fulcrum F by the collar C^1 and the pin P^3.

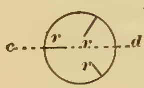
The plan of the bed frame is shown in Fig. 2, in which S.S. are the bed sills and Sm,Sm are the mud sills. Nailed to the top of the lever is a shallow wooden box W, which is weighted down with loose stones so as just to counterbalance the downward reaction of the water upon the pipe. It is apparent that this machine is so simple as to be readily set up, managed and kept in order by any workman of average intelligence. But, like many other simple machines (billiard cues, for instance), there are widely differing degrees of skill displayed by different practitioners. This is so pre-eminently true with regard to the giant

as to make the pipeman the essential and most important employe on the works after the installation is complete. In fact, the degree of economical success or failure of the enterprise is gaged by his skill. It lies in him to make or mar the business. It is, therefore, a sheer waste of money to put such a plant in the hands of a novice or of an unskillful pipeman. Quick perception, nerve, intelligence and good judgment all go to make up the ideal pipeman or bank foreman. (In small plants the two offices are usually combined.)

THE NOZZLE.

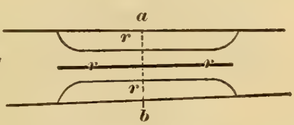
The nozzle N requires further notice. Upon the perfection of its shape and condition the cutting efficiency of the stream mainly depends. The cutting power of a stream of given volume and nozzle velocity is in the ratio of its solidity at the point of impact. Strictly speaking, a column or shower of spray has no

Fig. 3



Sec. on a b Fig. 4

Fig. 4



Sec. on c d Fig. 3

cutting power; it merely washes. But a solid stream with a nozzle velocity of say 90 feet (due to a head of 150 feet) pierces a bank like a projectile or bores like an auger. It surprises the novice to see what refinements of precaution are requisite to insure such solidity of stream.

First. No entrained air should be permitted to pass the nozzle.

Second. The bore of the latter should be of correct shape ("ajutage"), and, in the cylindrical part, should be as true and smooth as a gun barrel. Because iron soon becomes roughened by rust, hard gun metal is a better material for nozzles.

Third. Rifles or radial plates r, r, Figs. 3 and 4, should be inserted in the pipe to prevent the rotary motion otherwise bound to occur, which whirling motion of the column would destroy its cylindrical shape and solidity.

THE SLUICE LINE.

In gold mining, the boxes, Figs. 5 and 6, must be of planed, tongued and grooved lumber, so as to be perfectly water-tight, since the smallest leak would cause the loss of fine gold and

amalgam, and they must have costly bottom paving. But, for our purposes, any tolerably tight boxes of cheap, undressed lumber will answer. And here is our first advantage in point of economy over the gold miner. A further gain is in avoiding (usually) the costly bottom paving of the gold miner, no lining being required for small operations, say of 20,000 or 30,000 yards, while for larger ones 1 or 1½-inch plank bottom linings would usually be sufficient on moderate grades. The upper end of the boxes should be provided with flaring wings of temporary sheet piling.

Near the head of the upper box is placed an inclined grating, with spaces of such size as to arrest all stones too large to be carried freely by the current in the boxes. The rejected stones are forked over in a pile to one side of the line of boxes by a man stationed at the grating for that purpose. If required, these piles of stones may be carried or run out of the cut on a tramway as

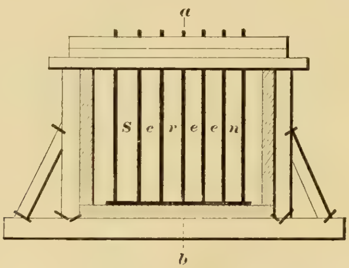


Fig. 5. Elevation of Upper End.

the work proceeds. The giant is set up a little to one side of the sluice head.

Everything is now in position to begin the cut. Fig. 7 shows in plan the relative positions of the sluice head S, the giant G and the initial point P. T.T. is the tramway for removing the piles of refuse R (including boulders, stumps, roots of trees, etc.). The stream from the giant is turned upon the point P. A cavity is rapidly formed in the base of the hill and a mixture of water, mud and stones pours down into the boxes. When the face of the cut approaches the limit of the giant's cutting efficiency, the work is stopped. The giant is taken up, a new joint or joints of pipe are added, and the giant set up in its new position. Especial care is demanded in securing the bed frame of the giant firmly in the ground. Small, sharp gravel or firm soil should be rammed hard around the mud sills, and the frame should be strongly braced against forward or lateral motion, because a very slight movement of the giant would loosen some of the joints in the pipe line.

The sluice head is carried forward at the same time with the giant, by adding boxes at the upper end.

When the bank attains a height of 15 or 20 feet, it is usually in a shape to begin the first cave. The foot of the bank is undercut several feet in height, forming a cave, or a series of caves with intervening pillars. When the caves are knocked into one by cutting out the pillars, the overhanging mass trembles, splits off on the plane of the back of the cave, and plunges into the cut with a momentum that shatters the mass. Now, the higher the bank the larger will be the amount of overhanging earth brought down by a given amount of undercut, whence the economy of high banks becomes apparent. Take the case of a bank like that at North Bloomfield, 400 feet high. Suppose the cut is 40 yards long, 2 yards deep and 10 feet high. The amount of undercut would be about 260 yards, and the amount caved down

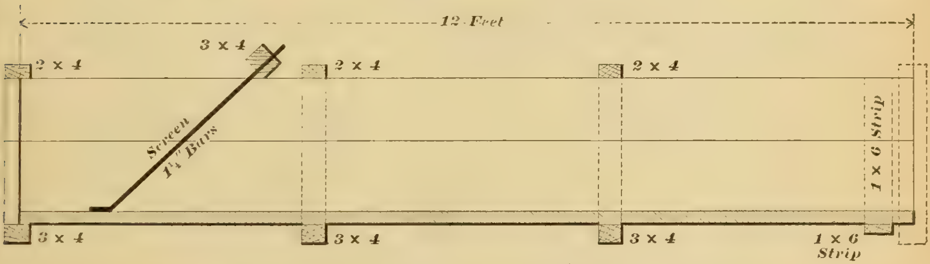


FIG. 6. SECTION OF ELEVATION ON LINE *a b*, FIG. 5.

would be over 10,000 tons. But such high banks are usually so dangerous that it is preferred to work them in two stages, as they were doing at North Bloomfield on the occasion of the writer's visit. But operations on such a scale would rarely, if ever, be demanded in engineering work. In railroad cuts of from 40 to 100 feet, for instance, it is not likely that more than from 2 to 4 second feet of water under 150 feet head (2 to 3-inch nozzles) would ever be required. In most cases, especially on high summits, the water would have to be delivered by steam power.

To recapitulate, in point of economy our practice is inferior to the great hydraulic mining plants in the following particulars:

First. In volume of water.

Second. (Usually) in amount of head or pressure.

Third. (Probably in most localities) in not having a natural or gravity supply and pressure.

But, on the other hand, we have the following advantages over any and every mining plant:

First. We may use cheaper boxes and sluice line.

Second. We avoid the expense of all the costly gold-saving devices and appliances,—*e.g.*, costly bottom paving in the sluice line, undercurrents, box-riffles, retort house and the loss of at least four days' time each month in "cleaning up" (collecting amalgam) and in repairing sluice line.

Third. We save the interest and sinking fund on the capital invested in the huge dam and reservoir, and in the scores of miles of main ditch.

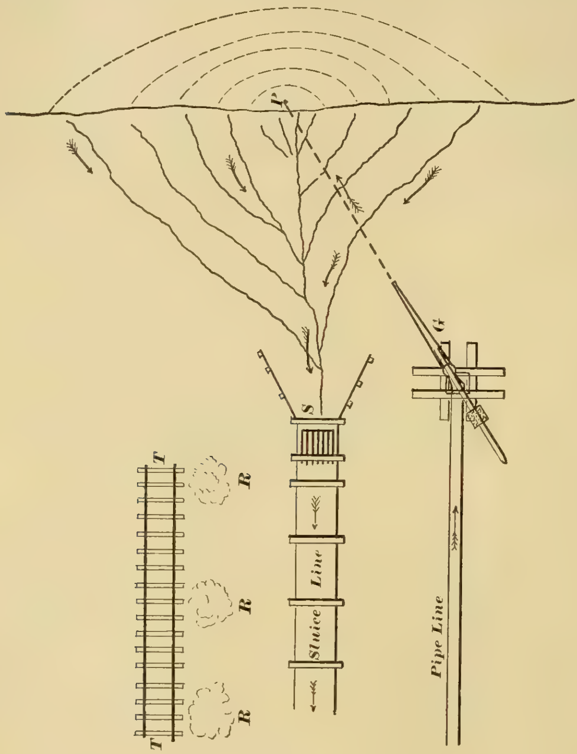


FIG. 7.

Fourth. The outlay, in railroad work especially, will be much smaller for giants, pipe line, tools and machinery for the cut than in mining.

As a deduction from the foregoing premises, we conclude that, under certain conditions, a great saving may be effected in the cost of the above indicated classes of engineering work by the use of hydraulic excavation, especially with the nozzle.

That this conclusion may not be relegated to the domain of abstract argument, your attention is called to the following recent

instances of the successful application of hydraulic cutting and filling in general engineering practice.

We will begin with extracts from "Reservoirs for Irrigation," by James D. Schuyler, Member American Society of Civil Engineers (United States Geological Survey Report, 1896-97, Part IV).

HYDRAULIC DAM CONSTRUCTION.

La Mesa Dam, San Diego, Flume county, Cal., for the purpose of storing the flood water of San Diego River, etc. "The dam was designed and constructed by J. M. Howells, C.E., President of the San Diego Flume Company. . . . It is an earth and rock-fill dam, 66 feet high and 20 feet wide on top, the materials for which were transported and deposited in place by flowing water, by the process known to miners as '*ground-sluicing*,' the surplus water from the flume being used for this purpose, and at the same time being stored in the reservoir as it was being formed back of the dam (page 649). The volume of material handled was 38,000 cubic yards, which had to be brought an extreme distance of 2200 feet, and stripped from an area of 11½ *acres to a mean depth of 2 feet.* Had the material been favorable in depth and character, it is thought the entire dam could have been finished for 25 or 30 per cent. of its ultimate cost, which was about $17,000. Instead of sluice boxes, the material was conveyed for the last 2000 feet in 24-inch wooden stave pipes lined with strips of steel to resist wear. Cost, 90 cents per foot. (Page 650.)

PROPOSED PINE VALLEY DAM, SAN DIEGO, FLUME COUNTY.
(Page 653.)

Dam to be 130 feet high, 30 feet wide on top. The water to be used for sluicing will have to be pumped to a height of 400 feet, in order to reach the deposits of material available for sluicing, but the engineer estimates that even this high lift is feasible and profitable, and he expects to increase the duty of water used from 5 per cent. of solids conveyed (the maximum accomplished at La Mesa Dam) to about 20 per cent. of solids, or 13 cubic yards per miner's inch of twenty-four hours (0.02 cubic foot per second). "If this duty can be maintained, and the cost of pumping be assumed at a maximum of 5 cents per 1000 gallons, the cost per yard for water will be about 5 cents, with but little additional cost for loosening (with pick), as the material is soft." (Please note that if giants were used *no additional cost for loosening would be incurred.*)

PROPOSED LAKE HELENA DAM, SAN DIEGO RIVER.

(Page 654.)

The proposed dam is 1100 feet long on top, 190 feet at base, 155 feet high, 25 feet wide on top, bottom thickness of 650 feet and to contain 789,000 cubic yards. "This site is considered favorable for hydraulic construction because of the abundance of material on both sides and the possibility of using *water under high pressure to loosen the material by powerful jets from hydraulic mining giants.*

DAM AT TYLER, TEXAS.

(Page 654.)

This dam, constructed in 1894, has the following features: Length 575 feet, height 32 feet, and contains 24,000 cubic yards. This impounds 1770 acre feet and covers 177 acres.

The water was pumped through a 6-inch pipe from the old city pumping station. This hill is 150 feet high and the pipe terminated halfway from its base, where a common fire hydrant was placed, to which was attached an ordinary $2\frac{1}{2}$-inch hose with a $1\frac{1}{2}$-inch nozzle. *The cost, including the plant and all the appurtenances of the reservoir, was $4\frac{3}{4}$ cents per yard.*

The following additional facts throw further light upon the secret of this remarkable result:

"The stream was directed against the face of the hill under a pressure limited to 100 pounds per square inch. The washing was carried rapidly into the hill on a 3 per cent. grade, which soon gave a working face of 10 feet or more, increasing gradually to 36 feet in vertical height. *By maintaining the jet at the foot of the cliff it was undermined as rapidly as it could be broken up and carried away by the water.*"

SAN LEANDRO AND TEMESCAL DAMS, CALIFORNIA.

(Page 655.)

These furnish part of the supply of the city of Oakland, having 60,000 inhabitants. They were constructed by their principal owner, Mr. A. Chabot, who had been a practical hydraulic miner.

The Temescal Dam was built in 1868. The work was continued a number of seasons by collecting storm water from time to time. The dam is 105 feet high and 18 feet wide on top, *covering only 18.5 acres*, with a capacity of 188,000,000 gallons.

The San Leandro Dam was built in 1874-75, and has a height of 120 feet above the stream bed. Total volume of dam is 542,-

700 yards, of which 160,000 yards were deposited by the hydraulic process. The water was brought four miles in a ditch, and the sluiced materials were conveyed in a flume lined with sheet iron plates, laid on a grade of 4 to 6 per cent. The water used was 10 to 15 second feet, and the ground-sluicing method was alone employed; *nevertheless the cost was estimated at one-fourth to one-fifth that of putting the earth in place by carts or scrapers.*

HYDRAULIC FILLS ON THE CANADIAN PACIFIC RAILWAY.
(Page 657.)

At trestle No. 374, North Bend, in Frazer River Canyon, there is required to fill the chasm an embankment 231 feet in extreme height and containing 148,000 cubic yards. The plant consisted of 1450 feet of sheet steel pipe 15 inches in diameter, 1200 feet of sluice boxes or flume 3 feet wide and 3 feet deep; one No. 3 "giant" monitor with 5-inch nozzle, and a large derrick driven by a Pelton water wheel. Piping head 125 feet. The sluice boxes were laid on grades from 11 to 25 per cent., partly supported on high trestles. The boxes were paved with wood blocks on the lighter grades and old railway rails on the heaviest. Fifty per cent. of the pit consisted of *cemented gravel*, 30 per cent. of loose gravel and 20 per cent. of large boulders which had to be removed by the derrick. Nevertheless, the entire cost of the work, including the plant, was $5089, or at the rate of 7.24 cents per yard (and including explosives used on the cemented gravel). "Had the pressure of the water been greater (400 to 500 feet head) and the gravel loose, *the duty of the water would have been increased four-fold.*"

The entire force employed consisted of eight men, all common laborers except the pipeman. The water used was approximately 20 second feet or 1000 miner's inches, the duty performed being 1.77 yards per twenty-four-hour inch. At the crossing of Chapman's Creek the railway company, in 1894, made a similar fill of 66,000 yards at a total cost of 7.5 cents per yard, of which 3.2 cents was for plant. The actual work of sluicing cost but *1.78 (one and seventy-eight hundredths) cents per yard.*

HYDRAULIC FILLS ON THE NORTHERN PACIFIC RAILWAY.
(Page 659.)

Work of a precisely similar nature has been in progress for a number of years past on the line of the Northern Pacific Railway, where several high and dangerous trestles have been replaced by hydraulic-made embankments of earth, gravel and loose

rock. During 1897, nine high trestles, requiring from 6200 to 108,500 cubic yards. Of this amount 377,000 cubic yards in eight of the trestles were moved and put in place at an average cost of 4.79 cents per cubic yard. The detail of the cost is given below:

Sluicing and building side levees	3.85	cents.
Hay used in levees	.09	"
Tools	.08	"
Lumber and nails	.22	"
Labor building flumes	.44	"
Engineering and superintendence	.11	"
Total	4.79	"

"In all the above work the water was carried to the borrow pits and the sluicing done by gravity. In one case, however, pumping was resorted to, and 42,250 cubic yards were moved by water thus lifted, at an average cost of *13.5* cents per cubic yard."

"The plant required is rather inexpensive. According to locality, one nozzle would require from 300 to 1000 feet of light sheet iron pipe costing 27½ cents a foot and a No. 2 giant costing $95. Outside of this nothing is required except picks, shovels, hoes and axes. From five to six men are required with each nozzle to build the levee, build sluice boxes and do everything else required."

THE DRAINAGE OF THE OKEFINOKEE SWAMP, GEORGIA.

In the "Engineering Society Annual of the University of Georgia," Vol. I, 1893, page 12, there is an article entitled "Hydraulic Excavation," by B. M. Hall, C.M.E., formerly a professor in the Georgia University. From this valuable paper we make the following extracts:

"Notwithstanding the fact that hydraulic gold mining has been in progress for so many years on the Pacific slope and in the State of Georgia, engineers seem slow to adopt this cheap plan of excavation for other work, such as railroads, canals, etc., even when the conditions necessary to successful operation are all present and in plain view.

"These conditions are:

"1. Material that is soft enough to be loosened and washed away by water.

"2. A sufficient volume of water at an elevation above the proposed cut.

"3. Sufficient grade, away from the bottom of the cut, for giving the water enough velocity to take away the material.

. . . Where booming is resorted to, for getting soft material out of the way, the cost is often as low as one cent per cubic yard. . . .

"The most important work of this nature that we know of is being done in Charlton county, Ga., by the Suwanee Canal Company, in excavating the outlet canal for the drainage of Okefinokee Swamp. That swamp, situated in Charlton, Clinch, Ware and Pierce counties, is a shallow fresh water lake, covering an area of 400,000 acres and filled with black muck. . . .

"The Suwanee Canal Company purchased the greater part of this land from the State of Georgia, and about 100,000 acres from individuals. The object of their undertaking is:

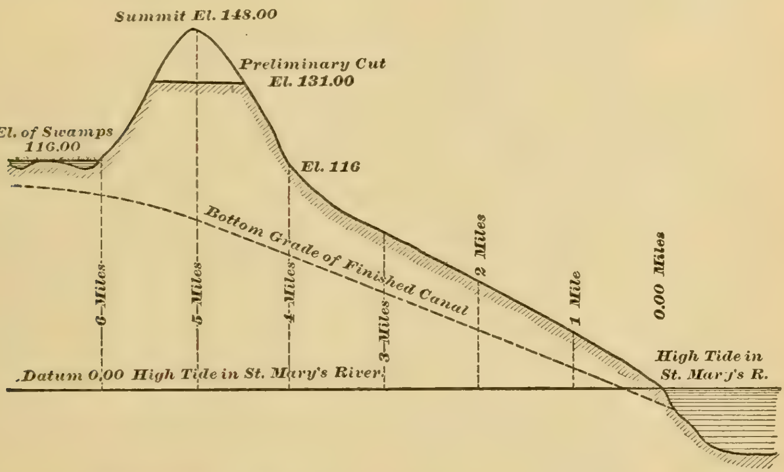


FIG. 8. DRAINAGE OF OKEFINOKEE SWAMP, GEORGIA. HOR. SCALE 1 MILE TO 1 INCH. VER. SCALE.

"1. To cut and place on the market this vast store of valuable timber, and,

"2. To thoroughly drain the lands for cultivation.

"A profile of the swamp and proposed drainage is shown by Fig. 8.

"In making plans for drainage, the first thing necessary was to provide a sufficient outlet by cutting a deep canal through the dividing ridge. It is here that the method of hydraulic excavation is being used on a grand scale and in a highly interesting manner. First, a narrow, shallow canal was cut across the ridge with teams and scrapers as in railroading. Its depth was about 17 feet at the summit, and it ran to nothing at each end, as its bottom was level across the ridge. . . . At the eastern mar-

gin of the swamp a pumping plant, consisting of two 80-horse-power boilers and two 14-inch centrifugal pumps, lifts 30,000 gallons of water per minute into a flume, producing an immense stream, which runs into and through the canal. At the eastern end of this preliminary cut, where the slope toward the mine is steep, the water began to do its work. A deep and wide canal is being carried rapidly back toward the swamp."

A "porcupine" harrow, made of a round log filled with harrow teeth, is dragged up and down the canal by steam power, a distance of 1000 feet. The excavated material is dumped into a lateral ravine of such storage capacity that nothing but clear water drains into the St. Mary's River. The average cost of excavation on the outlet canal is 2½ cents per cubic yard.

HYDRAULIC EXCAVATION AT SEATTLE.

The Seattle and Lake Washington Navigation Company is opening navigable tidal channels by dredging and the reclamation of tide lands adjacent to the business center of Seattle, Washington, by filling with the fine black sand dredged from the channels. Two powerful dredges are used, each with a capacity of 600 to 700 cubic yards per twenty-four hours, which is pumped from the bottom of the channel through 18-inch pipes, a distance of 2000 to 4000 feet, and deposited to a depth of 18 to 20 feet over the area to be reclaimed. Some 36,000,000 cubic yards are to be handled in this way, and 1500 acres filled in solidly to a height of 2 feet above tide. About 1,000,000 yards had been put in place January 1, 1897, the cost of which was 16 cents per yard by contract.

In conclusion, the writer desires to call the attention of the Club to what he considers a rare opening for an extensive and profitable hydraulic cut and fill in Cincinnati. The whole of Mill Creek bottom, between Hopkins street and Harrison avenue and between the Cincinnati, Hamilton and Dayton and the Baltimore and Ohio Railroads, could be filled in by piping down the northern end of Mt. Harrison, to a level, say, ranging from 70 to 90 feet above datum. In the writer's opinion, little, if any, explosive would be required, provided not less than 20 second feet of water were used and under a head of not less than 250 feet. The water would be pumped from the river at the mouth of Mill Creek into a temporary reservoir on top of the ridge south of Liberty street. The reservoir need be only large enough to perform the function of a standpipe in maintaining an even pressure. A vertical cut of at least 200 feet could soon be established, when, by taking

advantage of soft layers at the base in undercutting, immense masses might be caved down. After the caves the softer parts and finer stone could easily be piped away, leaving the larger merchantable stone to accumulate on the floor of the cut, perfectly clean. Assuming that the stone averaged 20 per cent. of the bank, and that it is worth on the ground 40 cents per cubic yard, the stone would pay 8 cents per cubic yard of bank toward the cost of excavation. On this basis the writer estimated, some years since, that the work could be done at 15 cents per yard net, provided not less than 3,000,000 cubic yards were moved.

STREET LIGHTING OF CITIES.

By Henry H. Humphrey, Member of the Engineers' Club of St. Louis.

[Read before the Club, November 21, 1900.*]

The proper lighting of streets in our modern cities cannot be overestimated. Their illumination is scarcely secondary in importance to the maintenance of grades and paving. When the streets are neglected until their surfaces have become uneven and unsafe, the necessity of illumination is heightened.

It is evident to any one at all observant that the recent developments in street illumination are in the direction of a uniform and diffused light, rather than along the well-beaten path of previous years which gave brilliantly lighted crossings and Egyptian darkness in the middles of the blocks. The development of the inclosed arc lamp and the growth of mantle gas lighting are illustrations of this point.

Some cities still cling to the old-style open arc lamp; notably the city of Chicago, which is still making all its increase with this type of lamp, and the city of Denver, Col., which is at present installing a new city lighting plant using open arcs for all but one of the circuits. It is reported, however, that this feature of this contract may be changed before the plant is completed and inclosed arc lamps installed throughout the city.

The question of the candle power of the lamp itself is one of importance, but is evidently not a "paramount issue." The old-style direct-current series open arc lamp is without doubt superior in actual candle power to any of the later types of inclosed lamps. Nevertheless, it is giving place very rapidly to inclosed arc lamps of either the direct current or alternating current type. Development along the lines of electrical progress is not always made in the interest of the public, or of the users of light. Many systems, improvements, etc., are developed by the manufacturing companies for the sole purpose of making an increased market for their goods. This development in arc lamps, however, passing from the open lamp to the inclosed lamp, is one that directly benefits the public and the user of light. Admitting that the candle power is considerably less, for the same expenditure of energy in the lamp, the light is so much easier on the eyes in the immediate neighborhood of the lamp, and the illumination is so much more uniform, that the result is far superior.

A comparison of candle powers between the direct-current open arc, the alternating-current inclosed arc and the direct-cur-

*Manuscript received December 10, 1900.—Secretary, Ass'n of Eng. Socs.

rent inclosed arc lamps, is somewhat uncertain, owing to the different methods employed by different observers and to the different standards of light used. In fact, the result of candle-power measurements of arc lamps has been so uncertain that very few authoritative data upon this subject have been published.

In Fig. 1 a series of curves, prepared by Mr. H. H. Wait, of Chicago, and presented to the Northwestern Electric Association, is reproduced here by his permission.

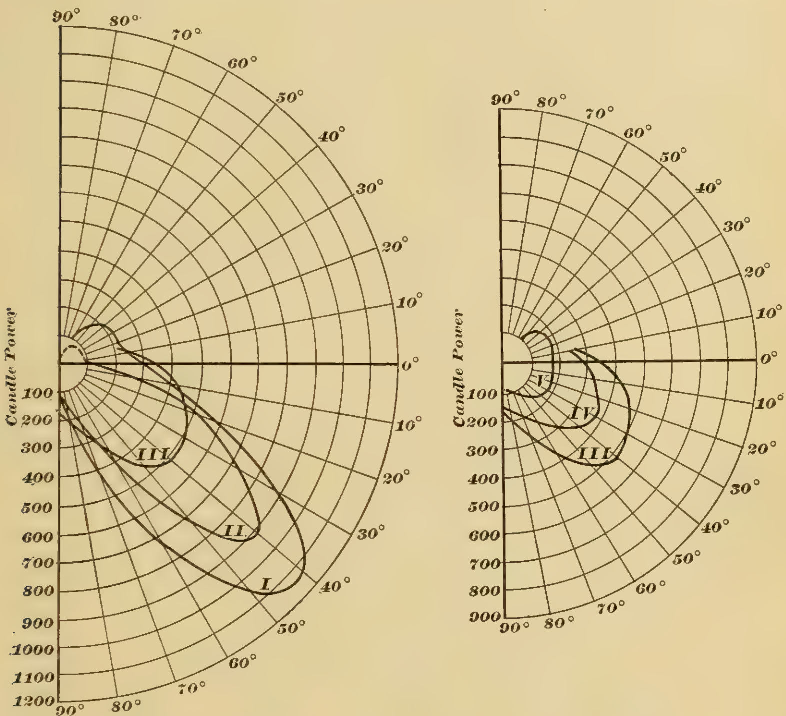


FIG. 1.

I— D. C. Open arc.
II— D. C. Inclosed arc, clear inner globe.
III—D. C. " " alabaster inner globe, with reflector.
IV—D. C. " " " " " " "
V— A. C. " " opal inner globe, without reflector.

No. 1 represents the direct-current open arc lamp.

No. 2, the direct-current inclosed arc lamp with clear inner globe.

No. 3, the direct-current inclosed arc lamp with alabaster inner globe and with reflector.

No. 4, the alternating-current inclosed arc lamp, with alabaster inner globe and with reflector.

No. 5, the alternating-current inclosed arc lamp, with opal inner globe and without reflector.

These curves show very decidedly the sacrifice of maximum illumination, in one direction, in order to secure a more uniform distribution of light and a better average illumination.

It is almost universally conceded that the direct-current inclosed arc lamp produces more light per watt than the inclosed alternating-current arc lamp, but the exact ratio between them has not, to my knowledge, been determined. The best data that I am able to find are the tests made by Prof. C. P. Mathews, of Purdue University, under the direction of the Committee on Arc-Light Photometry of the National Electric Light Association. His tests are based on constant-potential lamps, instead of upon series lamps, and his watt measurements are taken across the lamp terminals instead of across the arc only. He has tested 8 direct-current inclosed arc lamps and 7 alternating-current inclosed lamps, made by different manufacturers. The average difference in candle power between the direct-current lamps and the alternating-current lamps is 30 per cent., the average difference in watts consumed at the terminals of the lamp is 27 per cent.; the difference in watts at the arc is 12½ per cent.

Taking one particular case, comparing the performance of a direct-current 558-watt lamp, with no outer globe and no shade, with a 418-watt alternating-current lamp, with shade, gives a difference of 39 per cent. in light in favor of the direct-current lamp at an expenditure of 23 per cent. more power in watts. There is apparently but slight difference between the efficiencies of these lamps when the watts across the terminals are considered.

His data also give the watts at the arc in each of these lamps. The average watts used by the D. C. lamps are 529, of which 384 are available in the arc, and 144 or 27 per cent. are wasted in the dead resistance and in the mechanism of the lamp. The average watts used by the A. C. lamp are 417, of which 342 are available in the arc and 74.5 or 18 per cent. are wasted in the mechanism. If we reduce the results obtained, to the basis of light produced by watts in the arc, we find that the difference in candle power with the same expenditure of energy in the arc is approximately 16 per cent. in favor of the direct-current lamp. The average current for the direct-current lamps was 4.90 and for the alternating-current lamps 6.29.

Fig. 2 shows two curves from his data for 450 watts-in-the-arc arc lamps. In this figure, curves 1 and 2 are for the direct-

current lamps; curves 3 and 4 are for the alternating-current lamps. These are approximations only, since the candle power of the lamp varies greatly with different makes of carbons and with different current densities in the arc. These curves can be considered as approximating closely the conditions in series inclosed lamps, since in this type of lamp only 3 per cent. of the energy is used in the mechanism of the lamp.

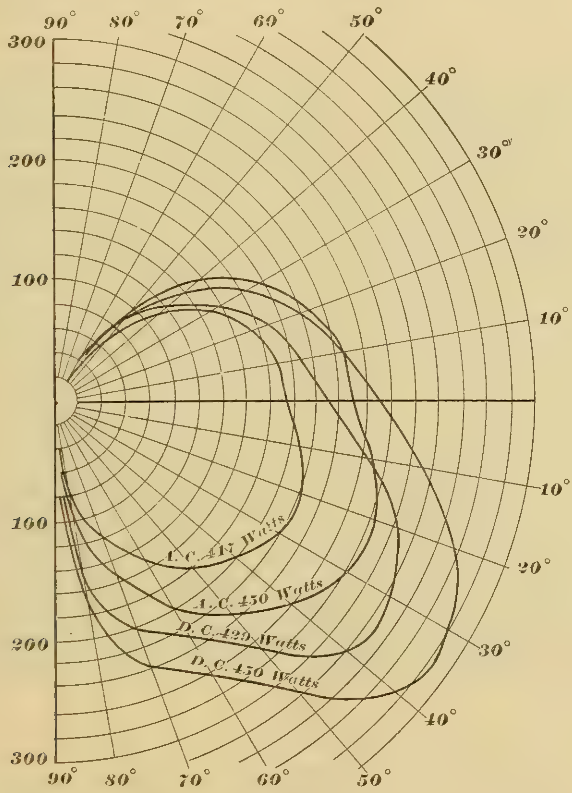


FIG. 2.

The company which recently secured the electric lighting contract in St. Louis for the next ten years proposed, at the time of the award, to build a new power house and plant complete, equipped for commercial lighting as well as for public lighting. Many of the contracts for machinery were awarded and actually signed, when the sale of the stock of the company to local interests changed entirely the scheme and development of the plant. Believing that the engineering details in connection with this work may have some general interest, I will describe briefly the

principal engineering features connected with the new electric lighting system in this city.

The general design of this plant, as installed, was outlined in the report of the engineers of the Imperial Electric Light, Heat and Power Company, under date of September 3, 1897, as follows:

"In an enterprise of this magnitude it seems to us advisable to bear in mind the possibility of doing the city lighting from this same plant. For a steady load, such as all-night street lighting, when the generators can be worked to their full capacity during their entire run, there is no apparatus that surpasses the direct-current machine and series direct-current arc lamp. The new series inclosed 150-hour arc lamp is being put upon the market now and the reports that we have from it are entirely satisfactory. Large direct-current multiple-circuit series arc lighting generators can now be obtained, suitable for direct connection to engines, and give a large and efficient unit without the necessity of excessively high voltage. We believe that this type of generator would fulfill the requirements of city lighting better than any alternating current or constant potential direct-current apparatus would do."

Anticipating the city lighting contract, the company installed one extra duct throughout its entire underground system, and a trunk line of ten extra ducts north and south to the limits of the underground district for the purpose of arc lighting. This foresight has made it possible for the present contractors for city lighting to install their work in the underground district within the time available, an accomplishment that would have been impossible for any company having to install an entirely new system of conduits.

The question of type of apparatus, whether to use the direct-current series inclosed arc lamp, or its formidable rival, the alternating series inclosed arc lamp, was promptly decided by the adoption of the former. The comparative difference in candle power of the two lamps, with the same consumption of energy, was unquestioned, and, since the city lighting contract calls for an expenditure of 480 watts at the arc, leaving the question of candle power entirely out of consideration, it was the desire of the company to give the public the benefit of the 16 per cent. increase in light.

Advocates of the alternating-current system claim that they can deliver more light from alternating-current lamps, operated from large constant-potential alternating-current generators,

than can be obtained from the use of direct-current apparatus. While this is an open question, and one dependent almost entirely upon the economy of the steam-generating and steam-using apparatus in the station, it did not enter seriously into the consideration of design of plant under the existing conditions. The Imperial plant was already in operation, with a direct-current system that had proved its efficiency and adaptability to the service intended; and the city lighting load, consisting of but 525 K. W., was too small a factor to affect seriously the design of

FIG. 3. MOTOR-DRIVEN ARC DYNAMOS.

the entire plant. It is admitted that driving these arc dynamos by means of compound condensing engines would be more efficient, from coal to watts-at-arc, than the present motor-driven units which, as shown below, give an efficiency of transformation of $80\frac{1}{2}$ per cent. About one-third of this $19\frac{1}{2}$ per cent. loss is probably in the motor, and could have been saved by driving direct from the engine. It is believed, however, that the practical advantages to be obtained from a plant of this design, where a multiplication of small units is avoided, where one man can operate the entire station, and where each large unit in the Imperial plant is a reserve unit for the city lighting work, are so great that

they overbalance the saving in coal obtained by placing the prime movers directly connected to the arc machines.

The arc lighting plant consists of 12 110-light Western Electric series arc dynamos, built upon their standard 125-light frames, and each machine guaranteed capable of operating 110 500-watt series inclosed arc lamps through 40 miles of No. 8 B. & S. circuit. Each two arc machines are driven by a 200 horse-power direct-current 500-volt motor, the three comprising a self-contained unit, five of which are capable of operating the present city lights, leaving one unit as reserve. These machines

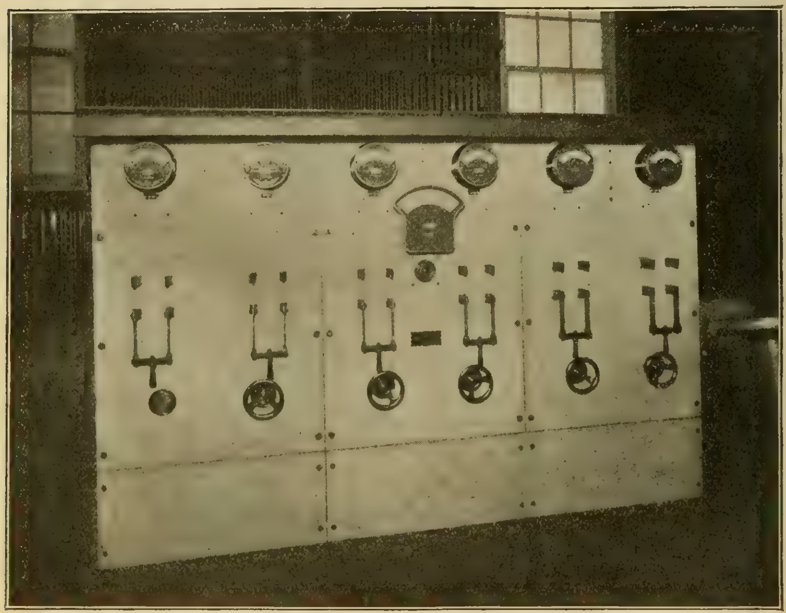


FIG. 4. 500-VOLT SWITCHBOARD.

are located at present in a temporary building adjoining the Imperial plant on the east side and located on the south side of St. Charles street, just west of Ninth street. In the design of the complete plant these arc generators will be on the second floor of the building, leaving the entire ground space available for boilers, engines and 500-volt direct-connected generators. Fig. 3 shows these machines.

Fig. 4 shows the 500-volt constant-potential switchboard, with switch, starting box, ampère meter, etc., for each motor-driven unit. The center of the board contains an illuminated-scale Weston 500-volt volt meter, showing the potential upon the

bus bars at all times. Inclosed fuses for each circuit are placed on the rear of the board.

Fig. 5 shows the arc board, containing 12 dynamo circuits and 12 outside circuits. The terminals are widely separated, the positive being at the top of the board and the negative at the

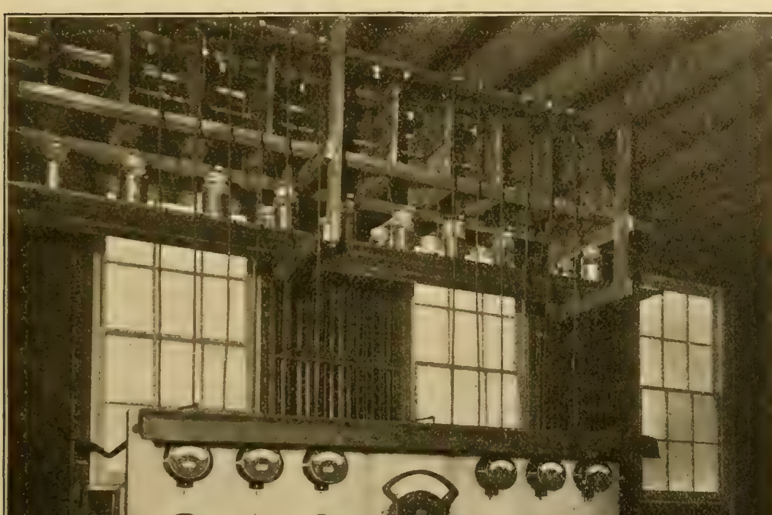


FIG. 5. ARC LIGHTING SWITCHBOARD.

bottom. Each circuit contains a combination Weston ampère meter and polarity indicator. There is a transfer bus across the middle of the board, so that a dynamo at one end of the board can be connected to a circuit at the other end without stretching long connecting cables across the front of the board. The center

of the board contains a Weston 10,000-volt volt meter with terminal plugs. There is also a plug for ground connection, and two plugs for 500-volt connection used for testing circuit during the day. At the rear and above the board can be seen the static arresters which will be mentioned later.

The arc machines are of the ironclad, Gramme Ring armature, bipolar type, each equipped with the well-known Western Electric regulator. A special lightning arrester is placed upon the pole of the machine in such a manner that the stray magnetism from the pole piece blows out the arc when a discharge takes place.

The motors are 6-pole ironclad machines, and operate at a speed of approximately 675 revolutions per minute. Each motor has a special field rheostat, by which the speed can be regulated through a range sufficient to provide for the variation in voltage due to commercial load on the station bus bars supplying the motors.

There are three circuits in the underground district, each containing approximately 105 lamps. These are supplied through No. 8 B. & S. lead-covered cables, manufactured by the Standard Underground Cable Company, having 6-32 inch rubber and 3-32 inch lead. The cables are drawn into the ducts in continuous lengths, from the base of the iron arc lamp pole on one corner to the base of the iron arc lamp pole on the next corner, thus avoiding all joints, either inside the ducts or in the manholes. The district north of the underground district is supplied by four overhead circuits, each containing approximately 90 lamps. They are carried through the underground district to its limit at Ninth and Wash streets, by means of a 12-conductor lead-covered cable, the 12 wires being placed in one cable and surrounded by a lead sheath $\frac{1}{8}$ inch in thickness. This cable provides for four extra wires for increase of plant or for use in case of trouble on any one conductor.

The district south of the underground is supplied by three circuits of approximately 90 lamps each, carried to the limit of the underground district at Seventh and Spruce streets through a similar 12-conductor cable.

For the overhead circuits triple-braided weather-proof wire is used, supported on double-petticoat glass insulator.

The lamps are suspended at the corners of street intersections by means of iron arc lamp poles. The interior of the pole, as shown in Fig. 6, contains a hoisting windlass and pulleys for raising or lowering the lamp. The figure also shows the method

of insulating the wires where they leave the iron pole and swing up to the lamp. The lead-covered cable is brought from the manhole, or service box in the street, through an iron pipe lateral, both cables of the circuit being placed in the same $2\frac{1}{2}$-inch iron pipe. In the base of the lamp they end in special hard rubber

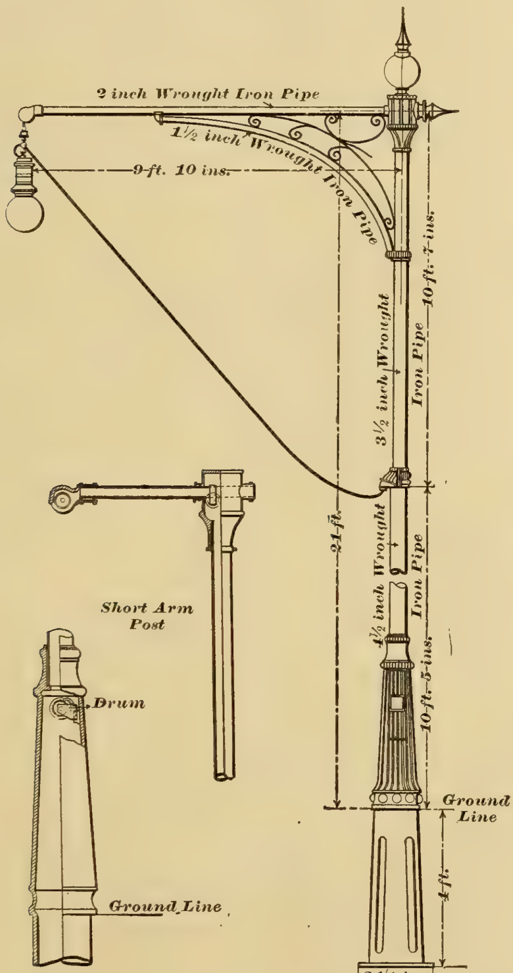


FIG. 6.

terminals, placed over the end of the lead sheaths and filled with paraffine to prevent any possibility of moisture entering the cable. From this special terminal a rubber-covered duplex cable, consisting of 2 No. 12 B. & S. flexible wires surrounded by 7-64 inch of rubber and the two conductors braided together, extends up

through the pole. This cable passes out through the special porcelain insulator and up to the lamp, being supported above the lamp upon a porcelain knob spreader and connected to a solid wire which enters the binding post of the lamp, providing a solid and secure connection at the binding post. These solid wires are bared for a short distance at a point midway between the porcelain knob and the binding post of the lamp, providing a space where a specially constructed "jumper" can be readily attached whenever it may become necessary for a lamp to be changed while the circuit is in operation. The linemen carry insulated stools upon which they stand while handling the live circuits.

The use of a switch in the base of these poles, by which the lamp could be cut out of circuit entirely while a lineman is working upon it, would be very desirable, and such a switch was installed before the plant was put into operation. It took a very short experience, however, with these switches, which were the best the market afforded, to convince all connected with the enterprise that they were a failure in the position in which they were placed. Being convinced that it would be impossible to design a practical switch which would occupy the limited space available in the base of these poles and still be safely operative upon 8000 volt circuits, they were abandoned entirely and the solid connection was made as above described.

The use of iron poles for the suspension of arc lamps was a condition of the city contract, which left the engineers no option. The use of special terminals and the cable above described in the underground district, and the use of special triple-petticoat glass insulators on the poles on the overhead circuits, will, we believe, render the circuits safe from anything but the ordinary mechanical accidents incident to any class of apparatus placed upon the streets of a city.

As intimated above, some trouble, due to the static discharge from the underground cables, was encountered. This was not unanticipated; but it was believed that drawing both cables through the same iron duct, where they enter the base of the iron arc lamp pole, would provide a sufficient connection between the two, so that the lead sheaths would be practically connected together throughout the entire circuit. At the plant all of the six cables of the three circuits were drawn into the same duct of the conduit and with the same object in view. It was ascertained, however, soon after starting the plant, that these contacts were not sufficient. The static effect from the cables manifested itself

in the short-circuiting of arc lamps through the insulation at the top of the inclosing globe, where the full difference of potential of the lamp is effective. The lead sheaths of all the cables were securely soldered together in the manholes where they enter the lateral which goes into the lamp poles. They were also connected securely together at the plant just behind the switchboard. These efforts had little, if any, beneficial effect upon the operation of the circuits. In addition to this, a special static discharger, shown diagrammatically in Fig. 7, consisting of an ordinary Leyden jar condenser, was connected to the copper of each circuit at the rear of the switchboard in the plant. Each condenser is provided with a revolving contact arm, driven by a small motor which alternately connects the condenser to positive wire,

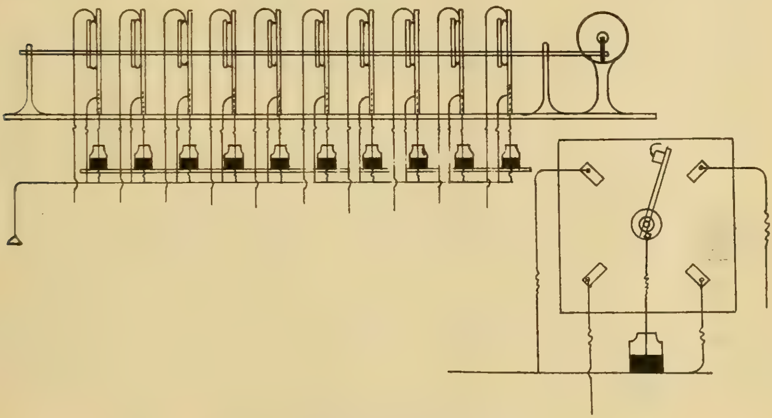


FIG. 7. STATIC DISCHARGER.

to ground, to negative wire and to ground, thus receiving a charge from the line and discharging it to ground about 30 times per minute. After this apparatus was installed the static effect of the cables has so entirely disappeared that it is not appreciable in the operation of the plant.

The city contract includes 739 32 candle-power incandescent lamps, located in the alleys throughout the electric-lighted district. These are all supplied from the regular 3-wire 235-470 volt mains of the Imperial Company, requiring, therefore, no special apparatus. It might be of interest, however, to show a special switch designed for switching these circuits in and out by means of the arc lighting current. This switch, which was designed by Mr. E. P. Warner, of Chicago, is shown in Fig. 8. When the arc current is turned on it operates upon the solenoid, which, acting through the lever, closes a 3-wire 500-volt switch, switching on

the alley incandescent lights throughout the district controlled by this particular switch. When the arc circuit is shut down in the morning the plunger of the solenoid is released, and, in falling, it opens the switch, cutting the incandescent lights out of circuit. This simple arrangement saves the services of a man, with horse and wagon, to go around and start the incandescent lights, saving also the loss of current in switching lamps on ahead

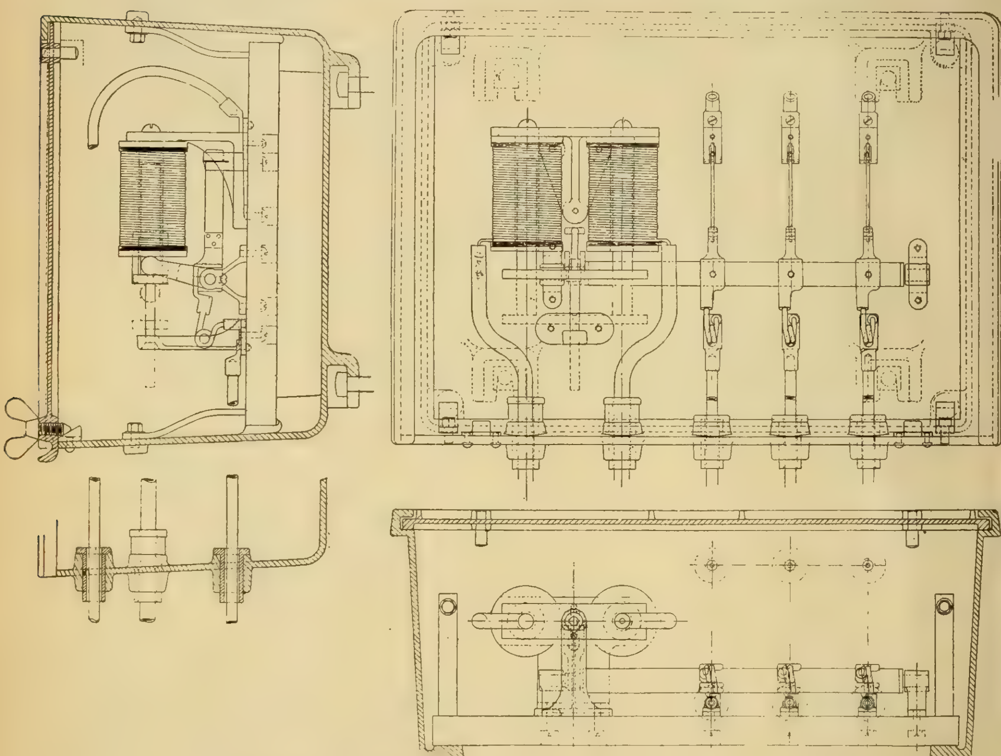


FIG. 8. 500-VOLT SWITCH ELECTRICALLY CONTROLLED BY ARC CIRCUIT.

of time where a considerable district must be covered and all the lamps in the district started not later than the schedule time.

In Table A are shown the data obtained under test of one of the motor-driven arc-light units, the test continuing from 12 o'clock midnight until the closing-down time in the morning. The first column gives the time; the second, third and fourth columns the ampères and voltage supplied to the direct-current motor, also the rise in temperature of the motor fields during the time of test. The fifth, sixth and seventh columns give the ampères, voltage and field temperature of one of the arc dynamos;

column eight and nine, the ampères and voltage of the other arc dynamo. Column ten gives the speed of the unit, column eleven, the temperature of the air in the room, and column twelve the efficiency, being the ratio of the electrical input to the electrical output of the unit. You will observe that each reading gives two

TABLE A.

TEST OF MOTOR-DRIVEN ARC UNIT.

Motor.				No. 7 Arc Dynamo.			No. 8 Arc Dynamo.		Speed.	Air Temp. F°.	Efficiency.
Time.	Amp.	Volts.	Field Temp. F°.	Amp.	Volts.	Field Temp.	Amp.	Volts.			
12-10	325 300	490 482	140	7.0 6.7	8580 8125	128	7.0 6 8	9346 8850	675	108 110	78.6
12-30	330 302	487 480	147	7.0 6.8	8791 8325	130	7.1 6.9	9346 8850	677	109 114	79.0
1-00	325 305	497 488	154	7.0 6.8	9425 8925	135	6.9 6.7	9610 9100	676	109 114	82.5
1-30	340 320	505 493	157	7.0 6.9	9610 9100	140	7.0 6 9	9979 9450	676	108 110	79.8
2-00	325 303	512 502	158	7.0 6.8	9610 9100	142	7.0 6.8	9504 9000	700	107 109	80.4
2-30	320 300	500 490	160	6.9 6.8	9346 8850	144	7.2 7.0	9187 8700	701	109 112	81.0
3-00	330 310	500 490	162	7.0 6.8	9504 9000	147	7.1 6.9	9557 9050	695	108 107	80 9
3-30	327 305	505 495	162	7.0 6.9	9400 8900	148	7.0 6.8	9504 9000	700	110 116	80.0
4-00	325 305	507 498	154	7.0 6.9	9504 9000	151	7.0 6.8	9610 9100	720	107 107	81.2
4-30	327 305	515 504	153	7.0 6.9	9557 9050	152	7.0 6.8	9820 9300	715	109 115	80.5
5-00	320 300	515 503	150	7.0 6.9	9900 9375	152	7.0 6.8	9504 9000	730	110 117	82.4
5-50	323 305	520 507	148	7.0 6.9	9451 8950	148	7.0 6.8	9583 9075		100 110	79.3
Average efficiency											80.5

figures, the first figure in each case being that of the standard test instruments, while the second reading is that of the regular station switchboard instruments. The test instruments read uniformly higher than the station instruments. They were carefully compared with recently calibrated instruments, and they are believed to be correct. The total capacity called for in each of

these arc machines, as given above, is 110-500 watt arc lamps each through 40 miles of No. 8 B. & S. wire. This is equivalent to a total voltage of 8750 volts at 7 ampères. The test shows that the machines ran above their rated load during the entire test, the load on one reaching as high as 9979 volts, which is 15 per cent. above the rating.

The guaranteed efficiency of the unit was $78\frac{1}{4}$ per cent. The average efficiency during test was $80\frac{1}{2}$ per cent., reaching, in one case, as high as $82\frac{1}{2}$ per cent. and in another 82.4 per cent. The machines came well within their guarantees regarding rise in temperature of all of their conductors. It will be noted that the temperature of the motor fields reached its maximum at 3 A.M., and from that time steadily decreased, although the work being done by the motor increased slightly during the test. This decrease in temperature is probably due to a slight increase in the speed of the unit following the high voltage at the bus bars. The voltage readings of the arc circuits show but slight increase during the night, after the number of lamps in circuit was allowed to remain constant. This increase of voltage is more noticeable on another type of lamp shown in the next table.

TABLE B.

Test of High-Voltage Arc Circuits.

Time.	No. 2 Circuit.		No. 1 Circuit.	
	Amperes.	Volts.	Amperes.	Volts.
6–36	6 5	5900	6.5	7000
7–00	6.5	6400	6.6	7300
7–35	6.5	6900	6.5	6500
8–00	6.5	7200	6.6	6900
8–30	6.5	7450	6.5	7400
9–00	6.5	7700	6.5	7900
9–30	6.5	7650	6.5	8350
10–00	6.5	7700	6.5	8550
10–30	6.5	7450	6.5	8600
11–00	6.5	7350	6.5	8750
11–40	6.5	7150	6.4	*6500
12–00	6.5	7150	6.5	6900
12–10	6.5	7100	6.5	6950

*Machine flashed just before reading was taken.

Table B gives data obtained from a test of another high-voltage plant in a neighboring city; column one gives the time, columns two and three give the ampères and voltage upon one

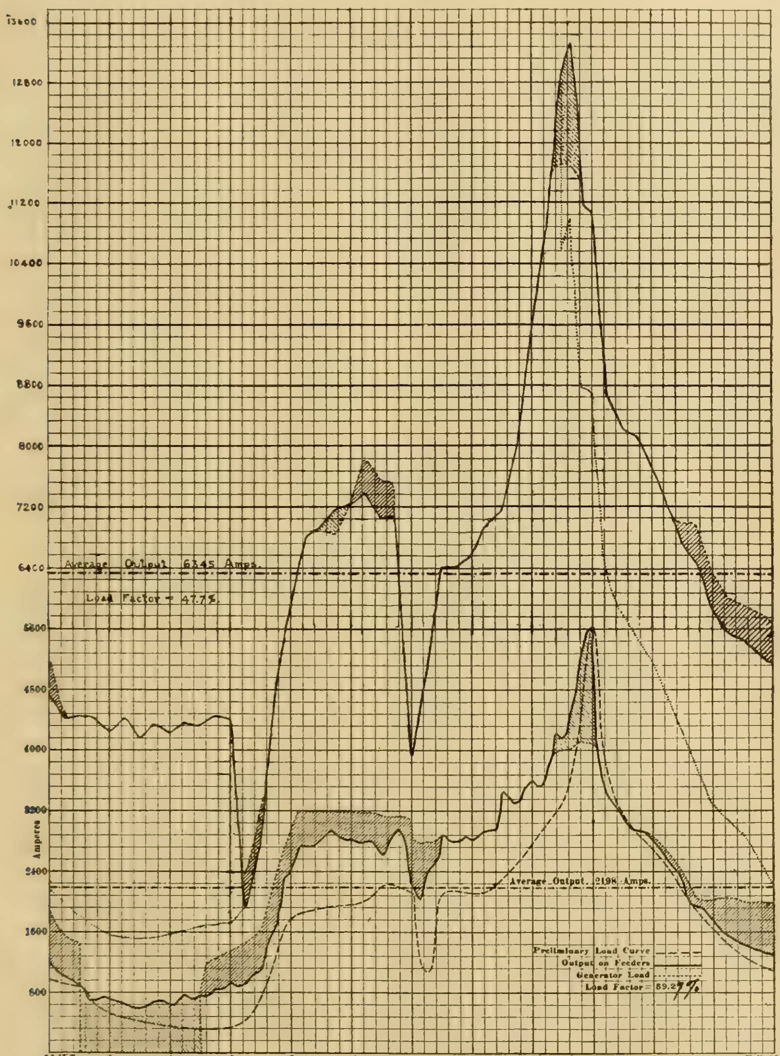


Fig 9. Load Curves, Showing Original Hypothetical Curve and Present Actual Curve with the Use of Battery Oct 1899 Also Load Curve Nov. 1900 Showing City Lighting Load

Fig. 9.

circuit and columns four and five the ampères and voltage on the other circuit. These were both overhead circuits. The former contained 92 lamps and the latter 110. This last circuit had 5 lamps more than either of the circuits shown in the last table.

These lamps, an hour after they had been put in operation, used but 64 volts per lamp, including the loss in the line. After they had been in operation for about five hours, however, the voltage per lamp had increased to 68 volts and 78 volts, respectively, for the two circuits, the lower voltage per lamp of one circuit being accounted for by a number of newly-trimmed lamps upon that circuit. This characteristic of an arc lamp is a serious drawback for street lighting, inasmuch as the lights show dim during the first part of the night, when people are upon the street and the light is needed, and show up much brighter during the latter half of the night when the streets are practically deserted, and when the light is not so essential.

In a paper read before this Club last year I showed the load curve of the Imperial plant, which I will reproduce in Fig. 9. I repeat it here for the purpose of showing what a small effect the city lighting load has upon the total load of the plant. The lower line gives the preliminary load curve, prepared by the engineers before the plant was built and submitted in their preliminary report covering the design of the plant. The second line gives the load upon the plant one year after it had started, and a year and one month ago. It illustrated the use of the battery at that time, and attention was called to the large all-night load, the comparatively low peak or maximum load and the high average for the entire twenty-four hours, which is 39.27 per cent. of the maximum. A year ago the peak of the load was 5600 ampères. The third or highest curve gives the present load-curve of the plant, showing the changed use of the battery, which is no longer able to carry the night load and allow the shutting down of the plant. It is still available for doing its full load capacity at the peak of the load, and its use as a balancer and equalizer of pressure is the same as it was a year ago. The increase in the all-night load is only partly due to city lighting, the city lighting load being only about half of the present total all-night load. The dotted curve shows the load on the plant exclusive of city arc lighting.

The station at present shows a maximum load of over 13,000 ampères, which is more than twice the maximum of thirteen months ago, which was 5600 ampères. The average load for the twenty-four hours has increased from 2198 ampères to its present amount of 6345 ampères, approximately three times as much as that of a year ago, and greater than the maximum load on the plant at that time. The load-factor of the plant has increased from 39.27 per cent. to 47.7 per cent., giving a load-factor that can be equaled by few, if by any, plants in this country.

WATER POWER BY DIRECT AIR COMPRESSION.

By William O. Webber, Member Boston Society of Civil Engineers.

[Read before the Society, November 21, 1900.*]

The use of compressed air for power purposes and as a means for the transmission of power is much older than is usually conceded. It was used by Smeaton in 1786, by Medhurst in 1810, by Rennie in 1812, by Vallance in 1818, at the Triger mines of Challones in 1845, by Cubitt in sinking the piers of the Rochester bridge in 1851. Brunel also made a similar use of it at Saltash in 1854. It was also used by Brunel on the Thames Tunnel, by Barlow on the Thames Subway and in the shaft of the Marie Colliery in 1856.

Air has been transmitted for considerable distances and under a great range of pressures. At the Mont Cenis Tunnel, air was transmitted to the boring machinery 20,000 feet under a pressure of 105 pounds per square inch. In the installation at Paris, in 1881, by M. Popp, the length of the pipes slightly exceeded twenty-four miles. This plant, as well as the one installed by the same person in Vienna in 1877, was originally used for the running and regulating of clocks, but it afterward developed into power for working small motors. In Paris the main is a steel pipe 20 inches in diameter, and the air, maintained at 90 pounds pressure, transmits 6000 horse power.

At a large compressed-air plant at Offenbach, near Frankfort-on-the-Main, air is distributed through 25,000 feet of cast iron pipe under 90 pounds pressure. At the Portsmouth Dock Yards, England, air is transmitted through 14,000 feet of pipe, varying from 3 to 12 inches diameter, under 60 pounds pressure, and is used to drive forty 7-ton capstans, five 20-ton cranes and machinery for working seven caissons.

There is also a large compressed-air plant at the Terni Steel Works in Central Italy. In this plant 1,200,000 cubic feet of air per day, under 75 pounds pressure, are used to drive a 100-ton hammer, a 100 and 150-ton crane and numerous engines.

In this country 2,500,000 cubic feet of air per day, at 60 pounds pressure, delivering 1700 horse power, are used at the Chapin mines in Michigan. The mains in this plant are 24-inch wrought iron pipes, one-quarter inch thick. Very successful compressed-air tramways have been operated for a number of years at Berne, Switzerland, and at Nantes, France.

*Manuscript received December 31, 1900.—Secretary, Ass'n of Eng. Socs.

Mekarski used compressed air for driving tramway cars in 1877.

In all of the above-named uses of compressed air, the compression was produced by steam-actuated mechanical compressors. The older ones were all simple compressors, Mekarski being the first to use compound compressors, and he was followed in this line by Northcote in 1878.

The adaptability of compressed air for various uses is very great. While electricity supplies power and light very directly, it cannot be used for heating except at a prohibitive cost. Gas is used very directly to supply heat, power and light, but is expensive for heating and power at the prices generally charged. City water pressure can be used to supply power, and indirectly light, by the use of a water motor driving a dynamo, but is too expensive for most purposes. Steam supplies heat and motive power almost directly, and indirectly light through a dynamo. It is, however, more expensive than compressed air, and involves more risk and attention. Compressed air can be used directly as a source of motive power, ventilation and refrigeration; also in the operation of elevators.

We have already mentioned its use in connection with power hammers, cranes and motors. For drying purposes it is even more efficient than heat. Compressed air is also largely susceptible to double uses. For instance, after it has been used cold, or without pre-heating expansively in a motor to produce power, the exhaust furnishes an efficient and cheap method of producing refrigeration. When pre-heated and then used through a motor the exhaust is still hot enough to contribute considerably to the heating of a building.

In the transmission of compressed air over long distances, the loss of pressure due to friction in pipes of proper sizes, and the loss due to leakage in properly constructed pipes and joints, are very small. Velocities of from 30 to 50 feet per second are allowable. When an air distribution system is introduced into a thickly settled community, the safety from the air main is much greater than from a steam main or a water main under pressure, and a leakage or even the bursting of such a pipe is attended with very much less damage.

Another great advantage in such a case is that power users require no new plant, and need incur no outlay for motors. Their present steam engines, with little or no alteration, are admirably adapted for serving as air motors.

Tests of small motors of from one to two horse power, using air at the ordinary atmospheric temperature and at 735 pounds per

square inch absolute, exhausting at from 33° to 54°, required a consumption of 1200 cubic feet of air per brake horse power per hour. At the Berne tramway the air is compressed to 450 pounds per square inch. On the average the cars use about 35 pounds of air per car-mile. This, however, was used in connection with hot water. In small motors of from one to two horse power, with the air pre-heated to a temperature of about 158° and exhausting at about the freezing point or 32°, 850 cubic feet of air per brake horse power per hour were used.

In some very carefully conducted trials made by Professor Riedler, using an 80 horse power engine which was actually giving 72 indicated horse power, using air at 80 pounds pressure, heated to 320°, with cylinders jacketed with hot air and exhausting at about 95°, about 425 cubic feet of air per brake horse power per hour were used. This showed an efficiency of about 92 per cent.

Practically all that has been said above refers to air compressed by the old methods of mechanical compression. We now come to the subject of air being compressed directly by falling water or under pressure. Air compressed by the ordinary methods of mechanical compression contains at least the same amount of moisture as the surrounding atmosphere from which it was compressed; and, in parting with the heat necessarily contributed to the air by the mechanical compression, it is inclined to absorb more moisture. There is incidentally a considerable loss of energy in parting with this heat. Air compressed directly by falling water is kept at the same temperature as this water. It is compressed isothermally, and the consequent expansion, when used in motors, produces an almost truly adiabatic expansion line. Tests, however, have shown that air compressed in this manner contains only one-sixth of the moisture originally in the surrounding atmosphere from which it is compressed. This is probably because the moisture in the bubble of air is pressed or squeezed out to its surface and then absorbed by the surrounding water. Incidentally there is no loss of power in parting with any heat, and there is a practical result which is of more importance,—the hydraulically compressed air can be expanded down to a temperature much below the freezing point, while atmospheric air, with the usual amount of moisture, mechanically compressed, cannot be used at all, owing to the freezing up of the exhaust passages of the motor in which the attempt to use it is being made.

During some tests made at Magog in September, 1899, owing to the conditions under which these tests were made, the change in the humidity in the air was not so great as above stated. The

moisture in the external air showed 90 per cent. of saturation, and, after compression, 29 per cent., or a little more than one quarter. In the Magog tests, using an old 75 horse power Corliss engine, with air at 53½ pounds gage pressure, with cold air direct from the compressor at from 66° to 73°, and exhausting down to the extremely low point of 42° below zero, 850 cubic feet of air per brake horse power per hour were used; and, with the air pre-heated to from 205° to 295° Farenheit, and exhausting at from 67° to 68°, 620 cubic feet of air per brake horse power per hour were used.

Probably one of the oldest applications of the use of water power to the wants of man was a form of hydraulic air compressor which operated as an entrainment apparatus. This was the well-known water bellows or trompe of the Catalan forges.

This apparatus, briefly described, consisted of a bamboo pole, disposed at a slight inclination from the perpendicular, into the upper end of which a stream of water was led, entraining air with it in its downward passage. The lower end of this bamboo pole was introduced into a bag made of the skin of some animal, the air being allowed to escape from the water into the upper part of the bag, whence it was led by pipes or tuyeres to the forge, the water being allowed to escape from the lower edge of the bag. From this original device a great many improvements have been worked out, and besides this a number of other forms of hydraulic air compressors, or of compressors using other liquids for compressing air or other gases, have been designed.

Siemens invented an apparatus on the principle of the steam injector, but the use of this was confined principally to the production of a vacuum. It is used to operate the pneumatic dispatch tubes in London. It has also been used for blast purposes in Siemens's furnaces and in sugar works.

Another quite ingenious device, Fig. 1, shown in a patent granted to W. L. Horne, consists of two flat plates, A and B, inclosing between them an air space from which a pipe leads to the atmosphere. The upper plate A is perforated with conical holes, the smaller end of each hole being adjacent to the air space between the two plates. Directly opposite the apertures of the upper plate A are corresponding conical apertures in the lower plate B, with the smaller end of the aperture next the air-space, the lower and larger part of the conical openings being prolonged by tubes C C. The upper plate is kept under a head of water, and the water jet, passing across the thin air space referred to, draws in the air through the large air pipe D, and compresses it through the smaller orifices.

Another device, using a somewhat similar principle, was invented by M. Romilly. It consists of a conical tube attached to an air reservoir by its larger end, and having a check valve interposed in the passage so as to prevent the air from escaping. Water is then injected into the smaller end of this conical tube through an ajutage which gives it the form of a liquid vein at a given pressure. This vein entrains the air with it and causes it to be compressed in the reservoir.

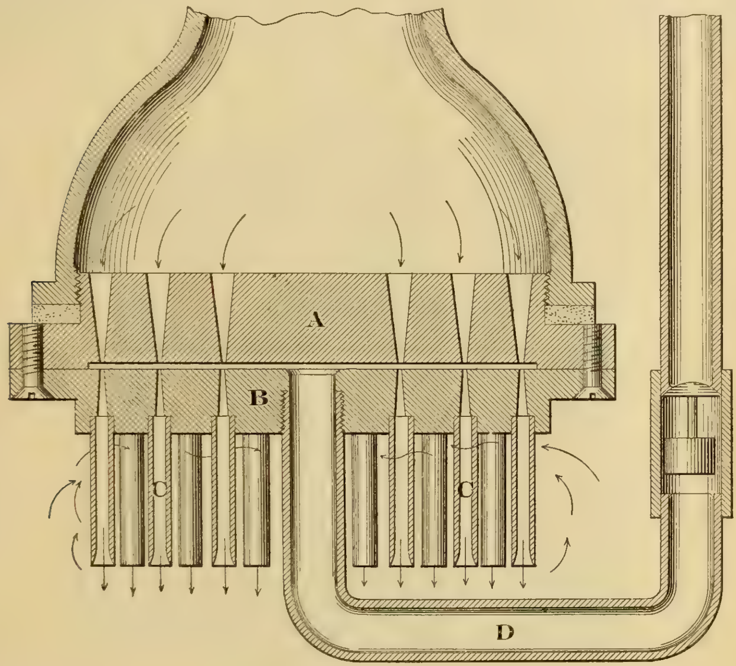


FIG. I. W. L. HORNE.

But all of the apparatus just described did not really employ the same methods as those used in the old trompe. One of the first inventions carrying out this idea, Fig. 2, was made by Mr. J. P. Frizell, of Boston, Mass., a member of this Society. His invention made use of an inverted siphon having a considerable horizontal run D between the two legs A and B. A stream of water was led into the upper end of the longer leg A, and at the top of the horizontal run D between the two legs of the siphon was provided an enlarged chamber C in which the air separated from the water. The water was then led off from the lower part of this air chamber and passed off through the short leg B of the siphon, the pressure of the air accumulated in the air chamber being there-

fore due to the height of water maintained in the shorter leg of the siphon. This application of carrying upward the water, after the air was separated from it, so as to produce a considerable pressure upon the air, seems to have been original with Mr. Frizell, and in this feature his device differs from the old trompe.

Mr. Frizell made two working models of this type of apparatus. In the first the legs of the siphon were 3 inches in diameter, the head of water being 25 inches, and an efficiency of 26½ per cent. was obtained. A larger apparatus was then constructed at the Falls of St. Anthony, on the Mississippi River, a few miles above

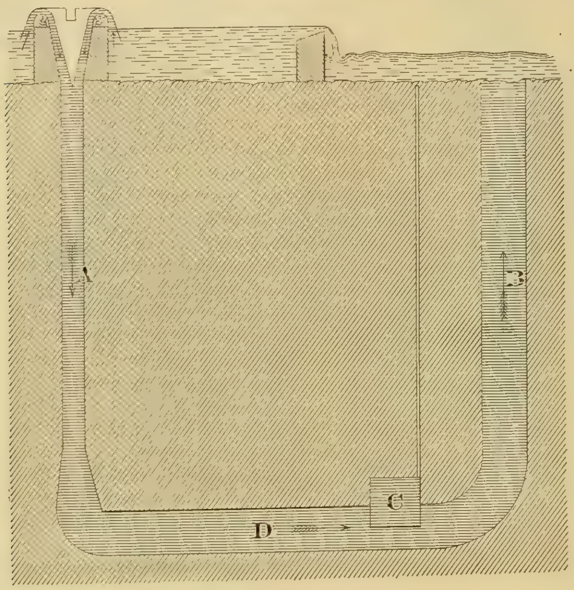


Fig. 2. J. P. Frizell.

St. Paul. The longer leg of the siphon in this plant was 15 inches by 30 inches and the short leg of the siphon 24 inches by 48 inches in section. The height of water above the air chamber was 29 feet. The head in feet varied from 0.98 to 5.2, the first head being just sufficient to cause a flow through the pipes The working head varied from 2.54 feet to 5.02 feet and the efficiency from 40.4 per cent. to 50.7 per cent., the quantity of water in these cases varying from 5.92 to 11.89 cubic feet per second.

From his experiments Mr. Frizell estimates that with a shaft 10 feet in diameter, a depth of 120 feet and a fall of 15 feet the efficiency would be 76 per cent., and that with a head of 30 feet and a fall of 230 feet the efficiency would be 81 per cent.

Another device, Fig. 3, differing somewhat from that of Mr. Frizell, was invented by A. Baloche and A. Krahnass in 1885, and consisted of a siphon B carrying water from an upper to a lower reservoir, the lower end of the siphon being projected through an inverted vessel R placed nearly at the bottom of the second reservoir. Just beyond the bend of the siphon, and in line with the vertical axis of its longer leg, an air pipe T projected into the descending leg of the siphon, thus entraining the air with the de-

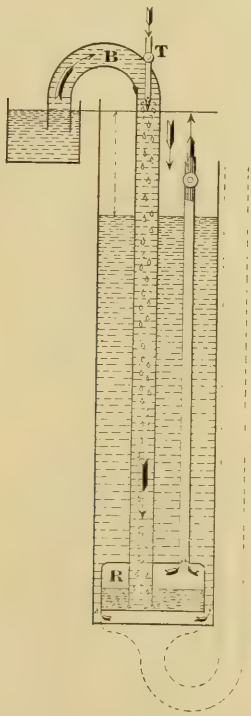


FIG. 3. A. BALOCHE AND A. KRAHNASS.

scending column, which carried it down into the inverted chamber R, from which the air escaped at the top, while the water passed out from the bottom into the lower reservoir. This apparatus produced pressure on the air in the top of the inverted chamber, due to the height of the water column upon it.

Another device, Fig. 4, patented by Thomas Arthur in 1888, differs from the last in having a stream of water led directly into the top of the vertical pipe A. Inserted into the mouth of this pipe was a double cylindrical cone C forming an annular air passage between it and the walls of pipe A.

Owing to the increase in the velocity of the water in passing through the narrow throat of the double cone, air is inhaled through the pipe D through the annular space mentioned and through perforations in the lower cone, and is entrained with the falling water.

Through the down-flow pipe A rises a vertical delivery pipe Z for the compressed air, having its lower end H enlarged and open at the bottom. Projecting upward into this enlarged air-delivery pipe was a water-escape pipe F through which the water passed after having parted with the air. This escape pipe was in the form

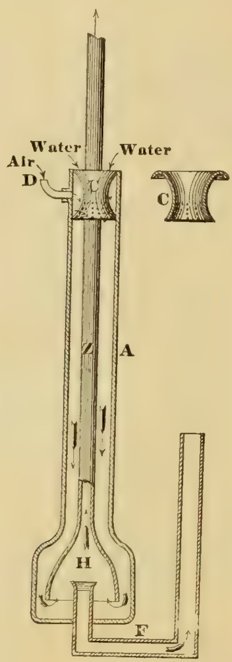


Fig. 4. T. Arthur.

of an inverted siphon and maintained on the air in the delivery pipe Z a pressure due to the elevation of the water at its discharge point above the air line in the large end of the delivery pipe.

A number of other patents on apparatus of this type were issued to Charles H. Taylor, Nos. 543,410, 543,411, 543,412, July 23, 1895. His inventions, Fig. 5, consisted principally of a downflow passage having an enlarged chamber at the bottom and an enlarged tank at the top. A series of small air pipes projected into the mouth of the water inlet from the large chamber at the upper end of the vertically descending passage, so as to cause a number of small jets of air to be entrained by the water, Taylor

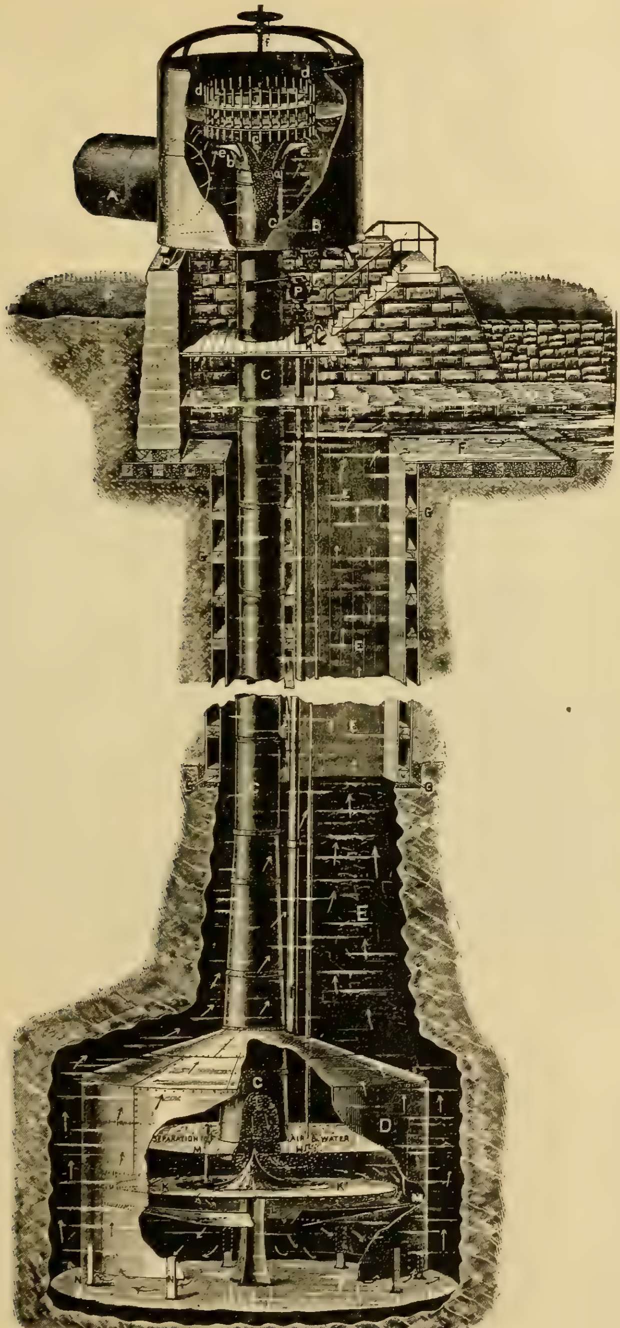


FIG. 5.

seemingly having been the first to introduce the plan of dividing the air inlets into a multiplicity of smaller apertures evenly distributed over the area of the water inlet.

Taylor at first seems to have attempted to utilize centrifugal action in causing the separation of the air from the water in the larger chamber at the bottom of the compressed column; but he afterward abandoned this scheme and used, instead, deflector plates in combination with a gradually enlarging section of the lower end of the down-flow column in order to decrease the velocity of the air and water and cause partial separation to take place. The deflector plates changed the direction of flow of the water. This was evidently intended to facilitate the escape of the air.

The latter improvements on this device have been in the method of introducing the air into the mouth of the downwardly flowing water column, so as to insure the largest proportion of air being taken down with the water, and in methods of decreasing the velocity of the combined air and water at the bottom of the descending column, causing the water to part more readily with the air, the water then passing out at the bottom of the enlarged chamber into an ascending shaft, maintaining upon the air a pressure due to the height of water in the uptake, the air being led off from the top of the enlarged chamber by means of a pipe.

The first of these compressors on the Taylor principle was installed at Magog, Quebec, to furnish power for the print works of the Dominion Cotton Mills Company. The head of water is 22 feet; the down-flow pipe is 44 inches in diameter, and extends downward through a vertical shaft 10 square feet in cross section and 128 feet deep. At the bottom of the shaft the compressor pipe enters a large tank, 17 feet in diameter and 10 feet high, which is known as the air chamber and separator.

A series of very careful tests on this plant demonstrated that with 19.5 feet head, using 4292 cubic feet of water per minute, was recovered the equivalent of 1148 cubic feet of free air per minute, which would represent 248 cubic feet of air per minute compressed to 53.3 pounds pressure, showing that out of a gross water horse power of 158.1, 111.7 horse power of effective work in compressing air was accomplished, giving therefore an efficiency of 71 per cent.

In the tests at Magog we recovered 81 horse power, using an old Corliss Engine without any changes in the valve gear as a motor; this would represent a total efficiency of work, recovered from the falling water, of 51.2 per cent.

When the compressed air was pre-heated to 267° F. before being used in the engine, 111 horse power was recovered, using 115 pounds coke per hour, which would equal about 23 horse power. The efficiency of work recovered from the falling water and the fuel burned would be, therefore, about 61½ per cent. On the basis of Professor Riedler's experiments, requiring only 425 cubic feet of air per brake horse power per hour, when pre-heated to 300° F. and used in a hot-air jacketed cylinder, the total efficiency secured would have been about 87½ per cent.

FIG. 6. MAGOG. COMPRESSOR HEAD AND WEIR. THE AIR COMPRESSOR IS BLOWING OFF.

The second compressor on the Taylor principle is located on Coffee Creek, to the south of Ainsworth, British Columbia. The Available head of water is 107.5 feet. The down-flow pipe is 33 inches in diameter. The shaft is 32 square feet area and 210 feet deep. The maximum volume of water is 4200 cubic feet per minute and would represent, at 71 per cent. efficiency, 587 horse power. This compressor is expected to utilize about 5100 cubic feet of free air per minute or 734 cubic feet of compressed air at 87 pounds pressure, and give an air motor horse power of 360 horse power.

It is possible, however, that this plant may not give as high percentages as this, as the water passages are of smaller areas than those at Magog.

Three other plants are now under construction,—one at Peterborough, Ontario; one at Norwich, Conn., and one in the Cascade Range, State of Washington. The plant at Peterborough, Ontario, for the Government of the Dominion of Canada, is to be used in connection with one of the locks on the Trent Valley Canal, the chief dimensions being as follows: Head of water, 14 feet; gage pressure, 25 pounds; diameter of compressor pipe, 18 inches; diameter of shaft, 42 inches; depth below tailrace, 64 feet.

The whole plant is inclosed in the masonry wall of the lock, the usual rock chamber in the bottom of the shaft being built in concrete and only a few feet below the lower water level of the lock.

At Norwich, Conn., at what is known as the Tunnel Privilege on the Quinebaug River, the plant will give 1365 H. P. of air at a pressure of 85 pounds per square inch. The head of water is 18½ feet; diameter of shaft, 24 feet; diameter of compressor pipe, 13 feet; depth of the shaft, 208 feet.

The air will be transmitted a distance of four miles with a loss in transmission not exceeding 2 per cent., through 16-inch pipe, which will be laid with flanged joints and rubber gaskets.

The plant which is being constructed in one of the canyons of the Cascade Range of mountains in the State of Washington will give 200 H. P. of air at a pressure of 85 pounds per square inch. Head of water, 45 feet.

There is no shaft, as the apparatus is constructed against the vertical walls of the canyon. The diameter of the compressor pipe is 3 feet. The diameter of the up-flow pipe is 4 feet 9½ inches. The capacity of the plant is based on 2000 miners' inches of water, equal to 53.2 cubic feet per second. The total height of this apparatus is about 260 feet.

Besides what is now known as the Taylor type of compressor, some forms of hydraulic ram compressors were designed by Sommeiler and also by Mr. H. D. Pearsall. These operated in a nearly similar manner to the hydraulic ram and gave an efficiency of 80 per cent.

A MODERN AMERICAN BLAST FURNACE—ITS CONSTRUCTION AND EQUIPMENT.*

By Arthur C. Johnston, M.E., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, November 27, 1900.†]

In an article written in 1896, entitled "Forty Years of Progress in the Pig Iron Industry," John Birkinbine says: "A retrospect of four decades will show that this interval covers most of the advances in the production of pig iron made in the United States, and also those introduced in European countries, for, although the use of mineral fuel, the application of heated blast and the employment of steam blowing machinery were not uncommon features of smelting plants, the increased production of pig iron up to 1855 was due chiefly to an augmented number of blast furnaces and enlarged dimensions of stacks. But what was considered at that time a large furnace would now rank as small, while the quantity of metal obtained in a year from the greatest producers of forty years ago was equaled by the monthly output of a number of modern furnaces in 1895."

The relative proportions of representative furnaces, from 1855 to 1900, are well shown in Fig. 1.

Much has been written about the increasing size and output of furnaces generally, but, on account of the rapidity of development, very little concerning their actual construction and the means employed for bringing about the increased production. The object of this paper is to describe the mechanical construction of a modern furnace, its equipment and the appliances for concentrating and handling the enormous amount of material that is required to make 600 tons of iron per twenty-four hours in a single stack; and to

*Note.—Owing to the keen competition of commercial interests in the iron and steel industry in this country, great care has been taken to eliminate from this paper anything that would seriously affect the interests of the company owning the furnaces herein described. It is on this account that the paper is confined to a description—from the standpoint of a blast furnace engineer—of the mechanical construction of a complete modern furnace plant, the object being to show thereby the great advances that have been made in blast furnace construction and equipment during the last ten years, and to give an adequate idea of the enormous possibilities of the American iron and steel industry, which has at its command such producers as these. The subjects of ore and coke supply, the burdening and grades of ore used, the fuel consumption and the extent and cost of output have been carefully avoided, otherwise the paper could have been made much more interesting and valuable.

†Manuscript received December 8, 1900.—Secretary, Ass'n of Eng. Socs.

draw some conclusions based on the operation of such a furnace, taking as a concrete example the plant of the Lorain Steel Company, at Lorain, Ohio. It is regretted that it will not be possible, within the limits of this paper, to introduce other furnaces for the sake of comparison, but it is hoped that the record of experience in the operation of the Lorain furnaces—two of the largest in the world—will be of value in the design of perhaps still greater iron producers.

The plant mentioned was built in 1899, and consists of two stacks, each 100 feet high from hearth level to furnace platform,

22 feet in diameter at the bosh and 14 feet at the hearth. By reference to Figs. 2, 3 and 4 it will be seen that they are arranged on the American system, which places two furnaces in a group, there being four heating stoves for each furnace and a boiler house and engine house common to both. The plant is arranged to be capable of extension by adding to the engine and boiler houses, making them of sufficient capacity for another similar group of two furnaces. Sections showing the lines and construction of the furnaces themselves are shown in Figs. 5 and 6. It will be seen that there is a slight difference between the lines of furnace No. 1 and those of No. 2.

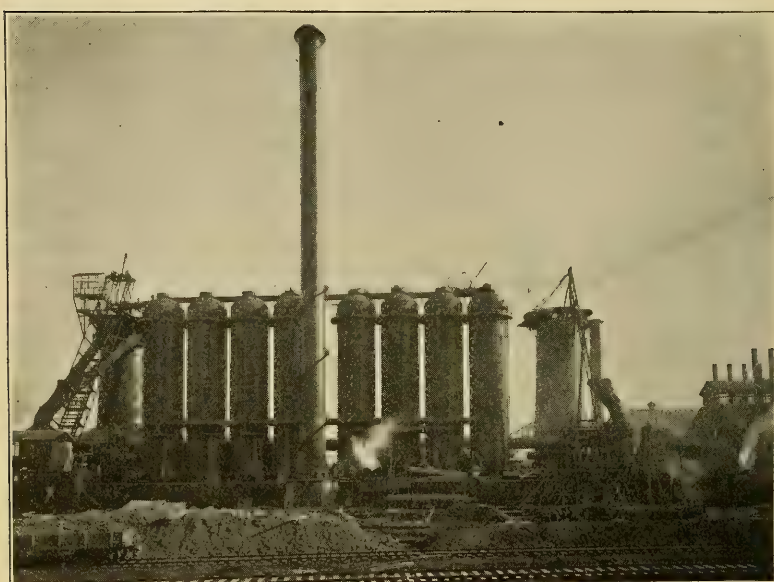
The distinctive feature of these furnaces is the great depth of the hearth jacket, and the low level to which the furnace columns

are carried in consequence. The hearth jacket itself is also of novel design. It consists of two series of segmental steel castings, held together by bolts and buckstays, with rust joints at the abutting edges of the different segments. Between the jacket and the masonry there is inclosed a complete ring of individual vertical pipes, intended to serve the double purpose of a cooling system and a means of relieving the jacket of excessive bursting strains, due to the expansion of the contained furnace bottom, by the partial collapse of the pipes. The intention was to have the cooling water for the jacket discharged into the annular space at the top of the same and to carry it downward through the pipes from which it would seek its level within the wall surrounding the jacket, whence it would be led off through a waste pipe placed at the desired level. In accordance with modern practice, the tuyères are spaced as closely as possible, there being sixteen 6-inch tuyères in the circle. A special feature is the great number of cooling plates. As will be seen in Fig. 7, there are twelve rings of bronze coolers, two of which are below the tuyères and three additional rings of cast iron coolers above the bronze plates. Fig. 8 shows clearly the construction of the coolers with their socket plates, and Fig. 9 the details of the tuyères. There are, in all, 277 bronze and 48 cast iron coolers in each furnace. The stock lines are protected by twelve rings of cast iron segments built into the brickwork. The mantels are built of $\frac{3}{8}$-inch steel plate, with two courses of $\frac{1}{2}$-inch plate at the bottom and one at the top. The gases generated in the stacks are led off through two downcomers, each 73 inches in diameter and brick-lined to 63 inches inside diameter. The general outline of these downcomers may be seen in the general plan of the furnaces, Fig. 4, and it will be observed that, owing to the steep angle at which they are carried up, it is practically impossible for dust to lodge in them at any point, which is a very important consideration. As a matter of fact, when the furnaces were blown out, after a year's run, these pipes were found to be as clean as a gun barrel. In the dust-catcher (Fig. 10) the direction of motion of the descending gases is so suddenly changed upward that ample opportunity is given for the precipitation of the dust, which can then be dropped into railway cars standing on the track which runs through the tunnel under the foundations.

The gases are further cleansed by being precipitated against the surface of a body of water in the gas washer (Fig. 11). From the washer the gases are led into the gas main. A by-pass, however, is arranged whereby the washer can be cut out of the system. This is accomplished by making two connections direct from the

dust-catcher to the gas main, controlled by 56-inch cut-off valves, which are fitted with water-cooled seats and discs. The connections from the dust-catcher to the washer, and from the washer to the gas main, are controlled by cut-off valves of a different type (Fig. 12). In Fig. 13 are shown the various connections between the downcomer and the gas main.

The gas main is a steel shell 85 inches in diameter and brick-lined to 75 inches, and it extends along the front of the eight stoves, having a downward connection to the burner at each of them. Here again precautions are taken to precipitate the dust



carried over by the gas; also in the burner itself there is still another dust-catching chamber. The stove burner is 18 inches in diameter, with a 6-inch air supply pipe (Fig. 14), and the opening for it in the stove is 22 inches in diameter.

Furnace gases are slow in burning, and for economical results a long combustion chamber of ample size must be provided. By reference to the section through the stoves (Fig. 15) it will be seen that the combustion chamber is carried up to the top, and that the burnt gases descend through the rectangular passages formed by the stove bricks, which are heated thereby until they reach the desired temperature. Each stove has a heating surface of 34,000 square feet. The gases are passed from the stoves to the chimney

through a 50-inch valve with air-cooled disc and water-cooled seat; the air is brought down through the stem, as shown in Fig. 16. The chimney is 10 feet in diameter and 225 feet high, and brick-lined to the top (Fig. 17).

In designing these furnaces it was figured that each of them would require from 45,000 to 50,000 cubic feet of air per minute, measured by piston displacement, when making 600 tons of iron each in twenty-four hours. To supply this volume the engine house is equipped with five horizontal compound blowing engines, with steam cylinders 44 and 84 inches in diameter, and two air cylinders 84 inches in diameter, all having a common stroke of 66 inches. The general design of these is shown in Fig. 18. The fifth engine is intended for a reserve, to be thrown on either pair of furnaces in the contemplated extension. They are designed to be capable of delivering air at a maximum pressure of 30 pounds per square inch, although the average blast pressure is only about 14 pounds. Any engine can be connected with either furnace at any time, as the two cold-blast mains run parallel with one another over the blowing cylinders, and each main has a connection with a shut-off valve to each cylinder.

The cold blast mains are 48 inches in diameter, and are rolled from $\frac{1}{4}$-inch plate. Each is equipped with a 48-inch snort valve, which in closing opens a $14\frac{1}{2}$-inch relief valve mounted on the same frame, and thus prevents a dangerous pressure from accumulating in the main when the blast is suddenly shut off from the furnace. In addition, there are three 8-inch safety valves on each pipe. Thirty-inch connections are made from the mains to the stoves (Fig. 19), and the valves in these branches have in their seats a smaller valve which opens first automatically and relieves the pressure, an arrangement which enables the main valve to be opened more easily.

The cold air from the blast mains passes into the stoves and up through the checker bricks, which have been previously heated by the burning furnace gases, and down through the combustion chamber—the gas burner having been withdrawn and its door and chimney valve closed—into the hot-blast main through a 32-inch hot-blast valve (Fig. 20). By referring again to Fig. 19 these connections will be readily traced. The hot-blast mains are 69 inches in diameter, and double brick-lined to 50 inches inside diameter. Before connecting with the bustle pipes, the hot-blast mains divide and join them with two connections in order to better equalize the pressure around the complete circle. From the bustle pipes the hot blast is led to the tuyères, and into the furnaces

through the tuyère stocks. Two 16-inch drop valves are placed on the bustle pipe. These open automatically when the blast pressure is shut off, and air is admitted instead of drawing dangerous gases back through the tuyères from the furnace; these also close automatically when the blast is turned on. Explosion doors are provided at the furnace top, and wherever possible in all pipes and chambers carrying gas.

For handling the stock at these furnaces an entirely new system is in use. The stock bins are placed underground (Fig. 21). There are five stock bin cars, with suspended weighing hoppers, for the two furnaces. The bins are 725 feet in length, and the ore, limestone and coke are delivered to the furnace skip car by the weighing cars, which draw their supply from the chutes in the bottom of the bins. The skip then carries the charges up the incline and delivers them at the furnace top, as shown in Fig. 22.

The stock bin cars are driven by two railway motors, and the door in the bottom of the suspended hopper is opened and closed by an air cylinder, the pressure being supplied by an electrically-driven air-pump carried on the car. The operator can weigh all charges from the car platform. The skip has a capacity of 240 cubic feet, and is hoisted, by means of four $1\frac{1}{4}$-inch cables, by a pair of 14 x 16-inch engines geared 6.5 to 1 to a 72-inch drum. To complete a single "charge" the skip makes four trips,—taking first two loads of coke and then two loads of ore and limestone mixed. Two loads of coke, or of limestone and ore, are kept always on the bell in order to act as a seal and to keep it cool. When making 600 tons of iron in twenty-four hours the skip delivers ninety "charges," making 360 trips to the furnace top, an average of a return trip every four minutes. The skip is counterweighted, so that the engine does work both in raising and in lowering it.

For pumping water for the cooling plates there are two compound, fly-wheel Holly pumps, each having two double-acting water plungers 22 inches in diameter, with a stroke of 28 inches. These are capable of delivering 7,000,000 U. S. gallons of water per twenty-four hours each. As a reserve there is also a duplex pump with two double-acting water plungers, 14 inches in diameter and 10 inches stroke. All these pumps deliver water to a stand pipe 12 feet in diameter and 150 feet high. The water passes through from three to four cooling plates before being discharged into the waste troughs. Arrangement is made also whereby water from the boiler-feed system can be sent through the cooling plates, in order to force out deposits of sediment by means of the increased pressure. Brass ball-and-socket unions are used throughout the piping for the cooling system.

The boiler house is equipped with 24 vertical water tube boilers, each of 250 horse power; so arranged as to use either furnace gas or coal as fuel. A cross-section of the boiler house is shown in Fig. 23, as is also the type of boilers used. These boilers are admirably adapted for furnace gas as fuel, as, on account of their great height, there is sufficient time to effect the complete combustion of the slow-burning gases. The gas main from the furnaces is extended into the boiler house, and has a connection to the burner in front of each grate.

With the increasing output from single furnaces, it was soon found to be practically impossible to handle the pig iron quickly enough when cast in sand beds in the ordinary manner; and this was the first cause of the development of the pig casting machine, which, with the mixer or storage tank, is one of the most important of recent inventions in connection with the blast furnace. Fig. 24 gives a general idea of the form of the machine. It consists of two endless chains carrying molds or chills of pressed steel, the details of which are shown in Fig. 25. In operation the machine is beautifully simple. The molten iron is poured from the ladle into a trough terminating in two spouts, from which it runs into the chills. The chain then drops down under the surface of the water contained in the tank, and travels under water for a distance of about 100 feet. It then turns upward, and as it ascends the incline the pigs are sprayed with cold water from a spray pipe; and by the time they reach the head of the machine they are sufficiently cooled to be loaded on cars which stand on the loading track. They may, as an alternative, be delivered by the machine to a conveyor, which in turn delivers them to the stock piles for use in the cupolas. The chains travel at the rate of 20 feet per minute, and the chills are spaced 12 inches center to center, so that each chain delivers 20 pigs per minute, weighing on the average 110 pounds each; and thus it will be understood how very efficient this machine is and what a great saving of labor it represents. Instead of clay washing the molds to prevent the iron from fusing with them, they are smoked by two smoke furnaces just before they pass over the tail sprockets. A set of chills will, under ordinary circumstances, last for nine months or a year. In cold weather, however, it is necessary to heat the water in the tanks, otherwise the repeated sudden and violent difference of temperature soon cracks the chills. The ladles are tipped by an electric ladle-tipping machine, from the spindle of which a connection is made with the hand wheel on the ladle car. Provision is made for casting in sandbeds at the furnaces, using the space inclosed by the retaining walls between the

two stacks and opposite the stoves; but this is done only in case of accident to the casting equipment.

Fifteen-ton ladle cars (Fig. 26) are used to convey the molten iron from the furnaces to the pig-casting machine. By referring again to the general plan it will be seen that these stand in a row on the hot-metal track which runs along the front wall inclosing the furnace foundations, and that the iron runners from the tapping holes terminate in spouts at a sufficient elevation to allow the iron to pour into the ladles. Similarly, the slag runners have spouts projecting over the cinder track, which is parallel to the end retaining wall. The cinder ladles (Fig. 27) are of 200 cubic feet capacity, and have removable cast iron linings, which can be renewed when worn out. The furnaces are tapped six times per day each, drawing off 100 tons of iron at each cast when working at their full capacity. The tapping hole is stopped up after the cast by means of a steam tapping-hole gun, which is shown in Fig. 28, as is also its method of use. It is suspended from a small jib crane attached to one of the furnace columns, and can be swung out of the way when not in use.

When the iron from the furnaces is to be used direct in the steel mill without remelting, the ladle cars containing the molten metal are taken to the mixer building, which contains a large mixer or storage tank which is capable of holding 300 tons of molten iron, and the general design of which is shown in Fig. 29. Here the ladles are lifted off the cars by an overhead electric traveling crane, and the iron is poured into the tank, which serves the double purpose of a reservoir from which the steel works can draw their supply and also of insuring a very much more uniform grade of iron, since all casts are mixed together. The mixer itself can be tilted by hydraulic cylinders to pour the iron into the steel works ladle. The iron is kept from chilling by means of fuel-oil burners inserted in the doors placed on the center of rotation and in the pouring spout.

Furnace No. 1 was put in blast July 5, 1899, and blown out July 14, 1900; furnace No. 2 was blown in August 23, 1899, and put out of blast July 19, 1900. During these periods No. 1 made 162,687 tons of iron, and No. 2 made 132,290 tons. They were seldom worked to their full capacity. Figs. 30 and 31 respectively show the lines of the furnace walls obtained by actual measurement immediately after cooling off; measurements were taken at four points of the compass, as indicated in the figures. It will be seen that the diameter of the bosh has increased considerably for the short blast; bronze plates in place of the cast iron coolers would

probably have held the lines better at this point, and several new furnaces are being so equipped. The cast iron rings protecting the stock lines were found to be badly warped inward; in many cases they had drawn the brickwork with them. This was probably caused by the high temperature at the furnace top when blowing out. However, it is very doubtful as to whether these rings are of any practical value. If they are used at all, they should be made light enough to prevent their warping from drawing the brickwork. There is a good deal of wear on the stock lines, as will be realized by referring to Fig. 32, which shows the profiles of stock as delivered by the bell; but with unprotected walls this would be evenly distributed all the way round, and the movements of the stock would probably be more regular on account of having no projections on the walls. The action of the bell and seal were very satisfactory.

The operators' houses were originally placed over the incline on each furnace top, which necessitated keeping two men in each house on account of danger from escaping gases, but later a single house was placed on the center of the stove platform, from which the bell apparatus for both furnaces was operated with much less expense and greater immunity from danger. The furnace top is equipped with six explosion doors placed directly under the platform. This proved to be a serious defect, as whenever gas leaking from these became ignited the mantel and platform were often badly warped by the heat; and in one instance the frame carrying the incline was also badly bent. This demonstrates the necessity of carrying the explosion-door frames out from the furnace clear of everything. The joints of these doors were originally made as shown in Fig. 33, a, but after the furnaces were blown out they were changed as shown in Fig. 33, b. The surfaces in this case were machined, and the door and frame brick-lined. The value of asbestos packing for doors that open frequently is very doubtful, as it soon becomes dry, hard and lifeless, which makes the prevention of leakage impossible. In another of the large furnaces recently built in this country the joints of the furnace-top explosion-doors were simply plain, flat, machined surfaces.

The cooling system of the hearth jacket was soon rendered ineffective by the stopping up of the pipes, due to leakages and small breakouts of slag from the bosh walls, which made it necessary to spray water on the outside of the jacket. The depth of the jacket is also unnecessarily great, and perhaps the only advantage of this type of jacket is that a section can be replaced when damaged by a breakout or other cause. The average amount of cooling water used for both furnaces was about 7,000,000 U. S. gallons per

twenty-four hours. This includes that used in the furnace-cooling system, and in the seats and discs of all water-cooled valves. The average rise in temperature of the water was 10.5° F. From these figures we may arrive at a very close approximation of the amount of heat carried away by the water. A complete system of cast iron runners for the hot metal was originally installed, but this was soon found to be useless and was dispensed with except at the spouts. There is a great difference of opinion in regard to the use of cooling plates below the tuyères; many claim that the tendency to chill the iron is too great, but it may be said that they were used with very satisfactory results in these stacks.

It is remarkable to what a small extent furnace designers have been guided by experience in the construction of heating stoves. Very many of the largest furnace plants have been badly crippled for long periods of time in order to allow the stoves to be reconstructed. The points of weakness are principally found in the plates forming the lower courses, and in the weakness of the stove fittings riveted to the shell. The plates of the bottom course in the Lorain stoves were $\frac{1}{2}$ inch thick, and many of these were badly cracked soon after the furnaces were put in blast. It will be seen, by referring to Fig. 19, that all the pipe connections are made at the bottom, and that cutting away so much of the plate makes it very weak. For a stove of this size, therefore, a plate not less than $\frac{7}{8}$ inches thick should be used. The flanges of castings, riveted to the stove shells, were about $1\frac{1}{4}$ inches thick, of cast iron. Many of these were also broken by the heat—especially the gas opening door—which caused bad and annoying leaks. These fittings were replaced by heavy steel castings, and no further trouble was experienced. Fig. 34 shows a gas opening door that has been very satisfactory. It will be noticed that the joint is of the spherical type, and that the door itself is brick-lined, which is the only sure way of preventing it from warping. The stove gas burner was originally designed 22 inches in diameter, with a 10-inch air-supply pipe, and the opening in the stove was made 28 inches in diameter. This burner was found to use too much gas, so that there was not sufficient for the boilers. It was modified to the dimensions shown with very satisfactory results.

The hot-blast valve (Fig. 20) is much heavier than the one originally used. The lighter valves were a great source of trouble, and in replacing them all the cast iron rings riveted to the shells were found to be cracked. All the castings, except the bronze water-cooled seats in the later valve, were of steel. On account of the hot-blast valve being opened and closed so frequently, and its

consequently greater liability to get out of order, another shut-off valve should be inserted between it and the hot-blast main; otherwise a crippled hot-blast valve cripples the furnace, since no pressure can be carried in the hot-blast main. The longer branch made necessary by the extra valve is also of great advantage, in that more freedom is allowed for the expansion of the main.

The blast temperature could be easily raised to 1200° or 1300° F. with these stoves. With large percentages of soft ores in the burden, however, it is found that a high-blast temperature causes a high-blast pressure. A 15-inch mixing pipe, connecting the cold- and hot-blast mains, was often found to be too small to reduce the hot-blast temperature by the desired amount, and a larger connection had to be made. An automatic controlling device, used with great success at another of the large furnace plants, was also contemplated. This consists of placing in the mixing pipe a butterfly valve, which is electrically controlled from the pyrometer, to keep the temperature of the blast within certain limits. The power necessary to move the valve is supplied by the blast pressure. At the plant mentioned it was found to be possible to keep the temperature of the hot blast within 5° above or below that desired.

One of the greatest sources of trouble at these furnaces was the "whipping" of the cold-blast main caused by the pulsations of the engines. This is an annoyance to which too little attention has been paid at many furnace plants, especially when it is considered how easily it can be avoided. The mistake is often made of trying to hold the pipe against these pulsations by strapping it to some solid foundation, but this can result only in loosening the rivets and causing leaks. All that is necessary is to provide a receiver of sufficient capacity to break up the column of air and absorb the pulsations.

The commercial efficiency of a furnace depends primarily upon the cost of delivering the raw materials of ore, limestone and coke at the furnace top, and of getting rid of its product as pig or molten iron. This plant is admirably situated with respect to its ore supply, for the reason that the ore is unloaded from vessels* directly to the stock piles without reshipment by rail. From the stock piles it is loaded by steam shovels into special pressed steel hopper-

*The dock machinery for unloading ore from vessels was fully described in a previous paper read by the author before this Club, and published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, January, 1900, Vol. 24, page 1, and in an article in *Cassier's Magazine,* September, 1900, Vol. 18, page 355.

bottom cars of 50 tons capacity, similar to the standard steel railway cars, but much shorter. These cars are then brought to the stock bins, and their contents are dropped through the hoppers, ready for use in the furnaces. Placing the stock bins underground has the advantage that no trestle with heavy grade approaches is required, but it is very doubtful whether the great cost of construction and maintenance is fully warranted on this account, as in cold weather the ore seems to freeze in them as readily as when placed in elevated bins. Limestone and coke are received by rail, and the coke is stocked by means of a traveling cantilever crane operating a grab bucket.

The plan of the furnace yard is shown in Fig. 35. All the tracks are of standard gauge, and the sharpest curve is of 461 feet radius. The hot-metal ladle car has a rigid wheel base of 7 feet 6 inches, and the 461-foot curve has been found by experience to be about as sharp as it can round. It is very important to have the tracks carrying hot metal as free from curves, grades and other complications as possible, as a ladle full of molten metal off the track is a very serious matter. It will be noticed, by reference to Fig. 26, that the ladle cars for hot metal are equipped with hand-tilting gear. This is certainly an unnecessary expense and complication for a modern furnace equipment. Wherever the ladle must be tipped—namely at the pig-casting machine, the mixer and in the ladle repair house—there are cranes at hand to do this, and the hand gear is a drawback rather than a help. Especially is this so at the mixer, where the ladles are lifted off the car and replaced thereon after pouring. A much more satisfactory ladle car would be one mounted on a pair of swiveling trucks, with simply the necessary supports to receive the ladle trunnions and a lock to prevent the ladle from tipping while in transit. A satisfactory ladle is one of the most necessary adjuncts to a modern furnace equipment.

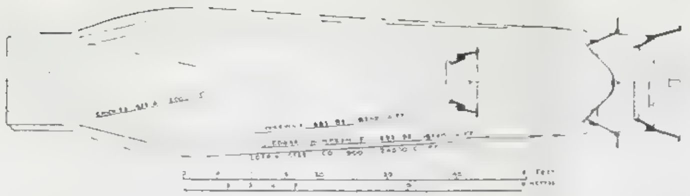


FIG. 1 COMPARATIVE PROPORTIONS OF REPRESENTATIVE FURNACES 1856-1900.

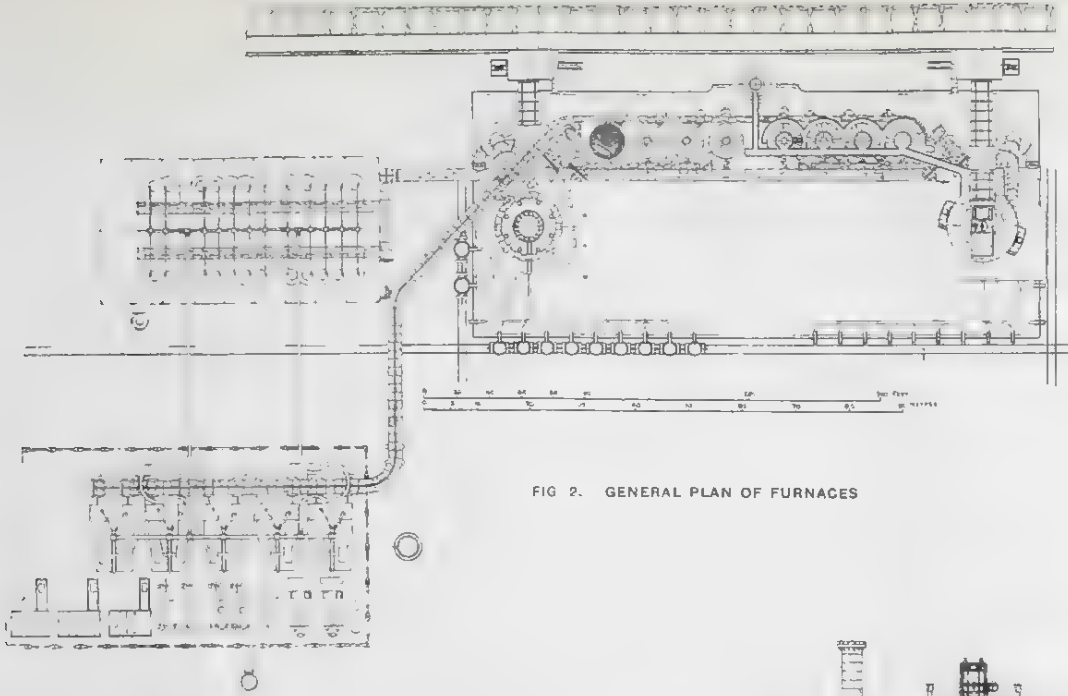


FIG 2. GENERAL PLAN OF FURNACES

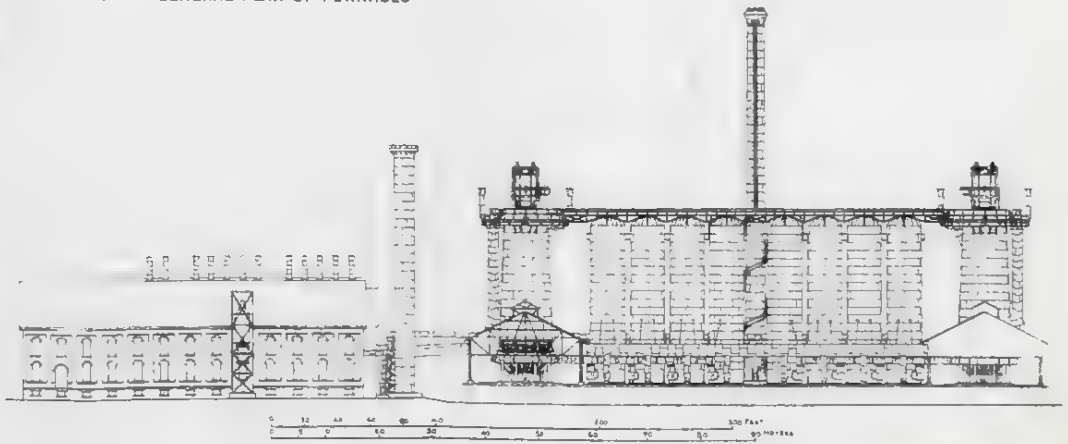


FIG 3 FRONT ELEVATION OF FURNACES

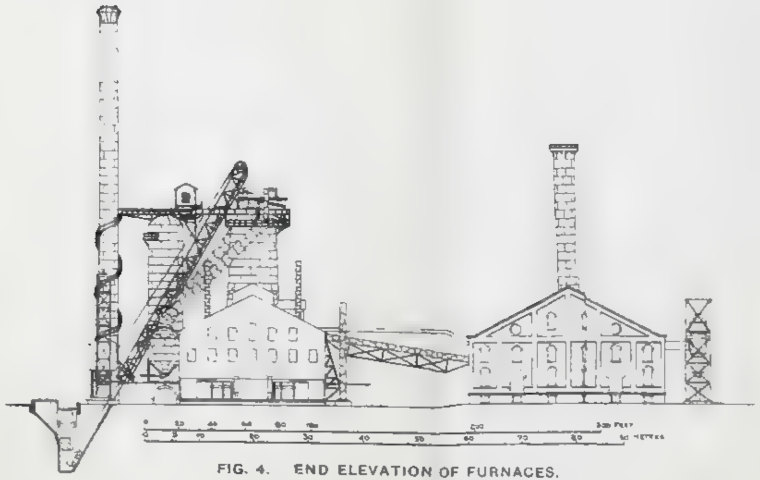
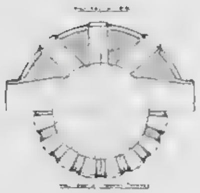


FIG. 4. END ELEVATION OF FURNACES.



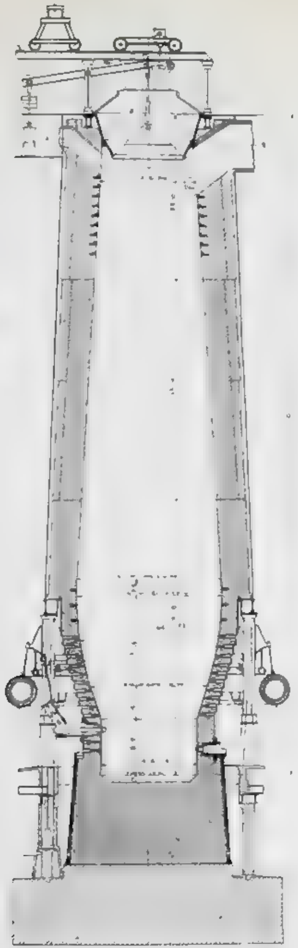


FIG. 5. FURNACE No. 1.

FIG. 6. LINES OF FURNACE. No 2.

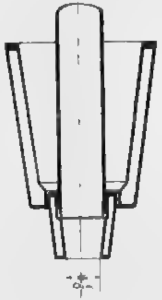


FIG. 9. DETAIL OF TUYERES.

FIG. 7. SECTION THROUGH BOSH WALL

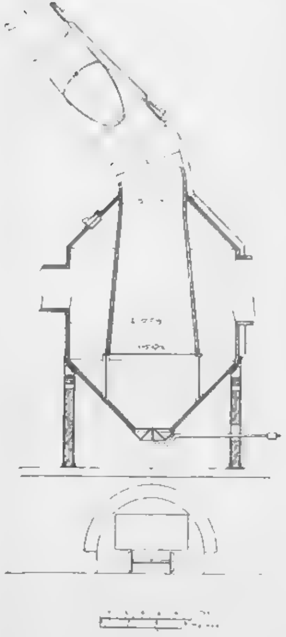


FIG 10 DUST CATCHER.

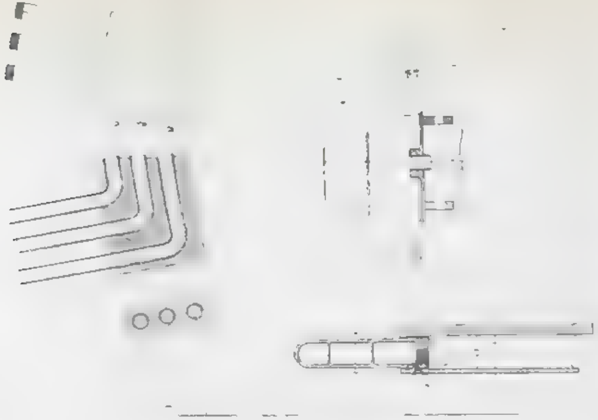


FIG 8 DETAILS OF COOLERS AND SOCKET PLATES

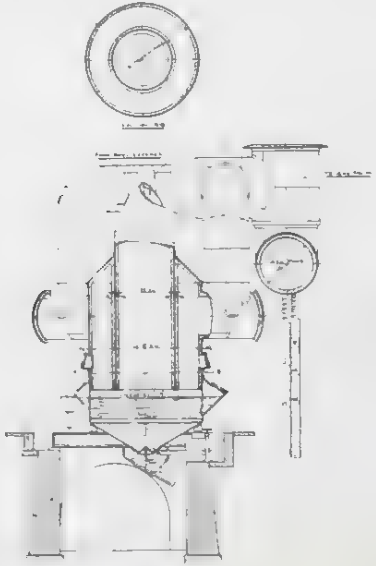


FIG. 11 GAS WASHER

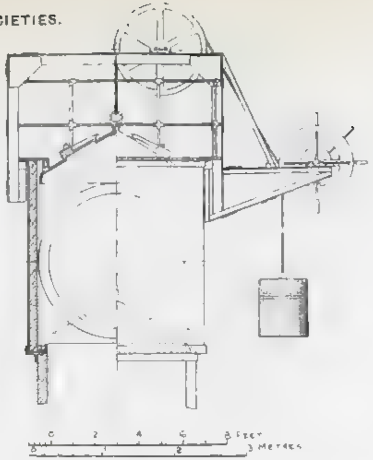


FIG. 12. 75 GAS CUT-OFF VALVE.

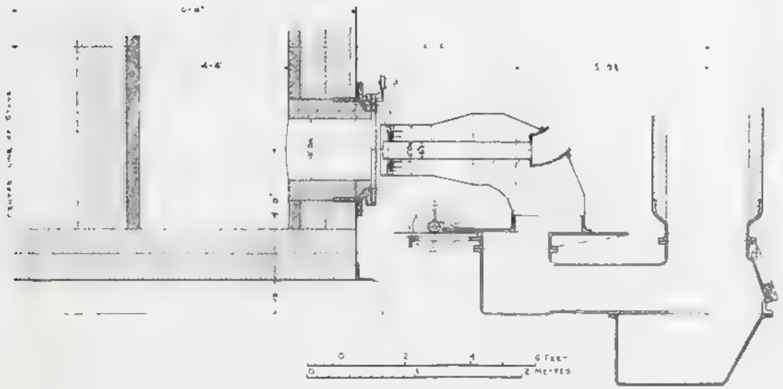


FIG. 14. STOVE GAS BURNER.

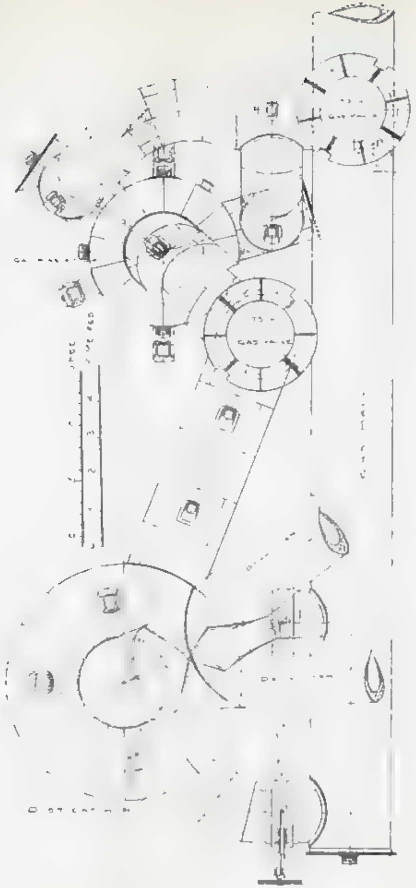


FIG. 13.

CONNECTIONS BETWEEN DOWNCOMER AND GAS MAIN

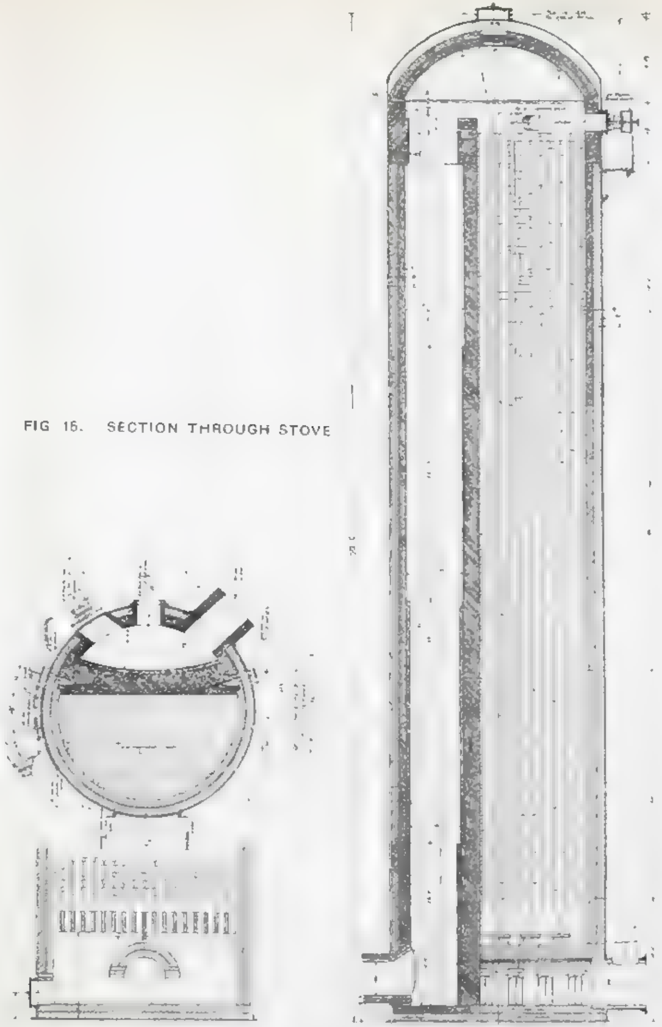


FIG 15. SECTION THROUGH STOVE

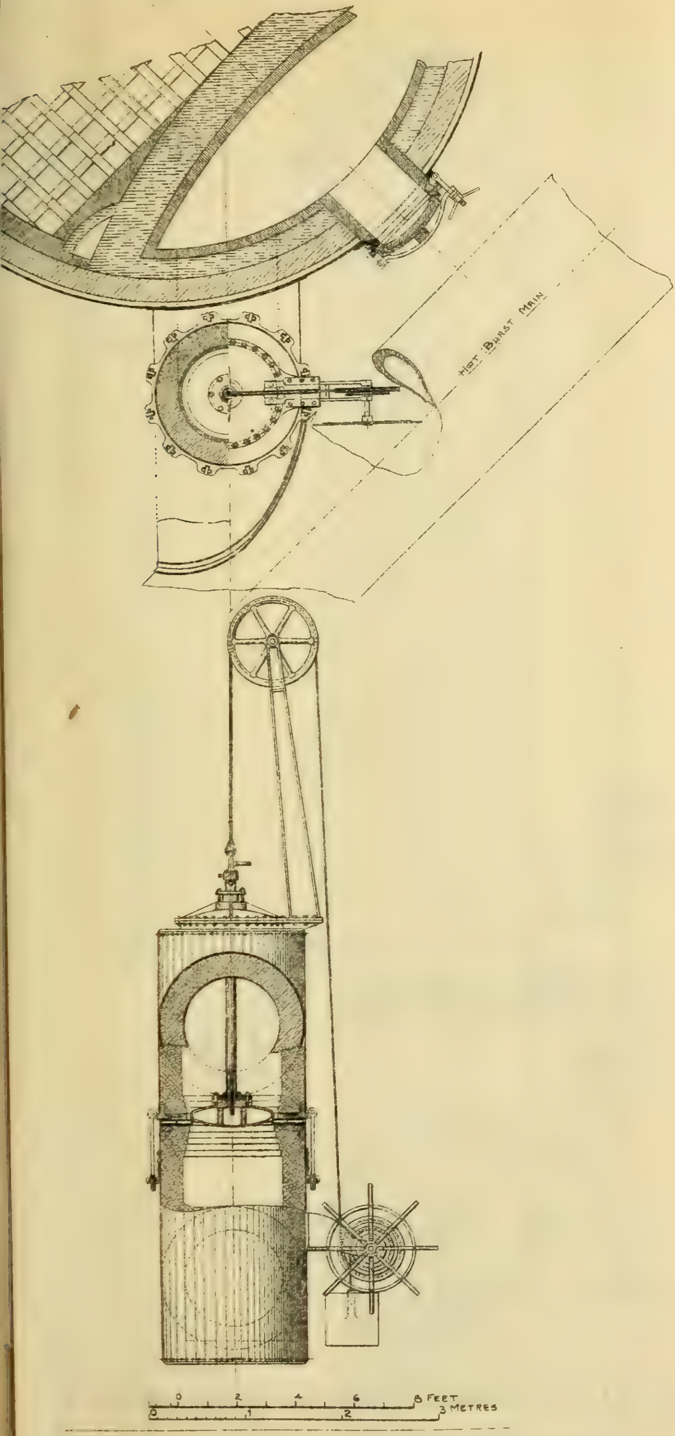
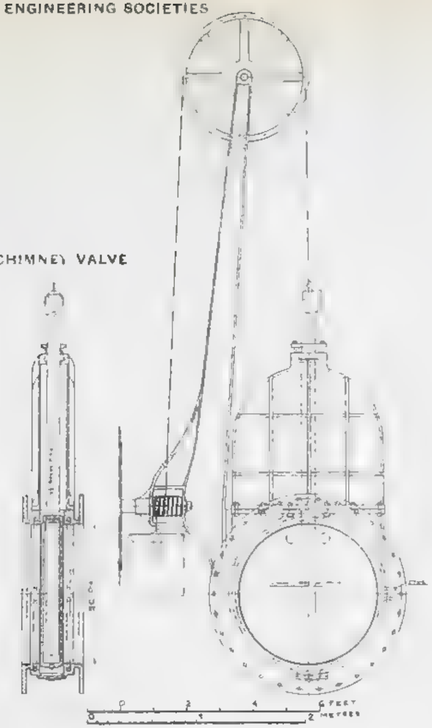


FIG. 20. 32″ HOT-BLAST VALVE.

FIG 16 50" CHIMNEY VALVE



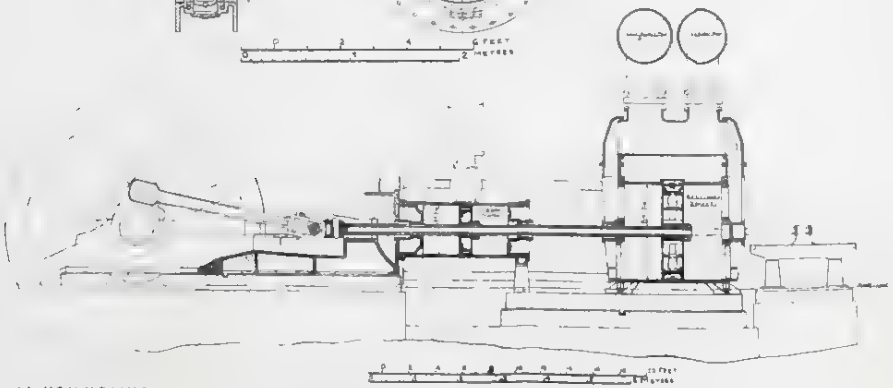


FIG. 18. 44 X 84' X 84' X 66' BLOWING ENGINES.

FIG. 17. 10' X 225' STOVE CHIMNEY

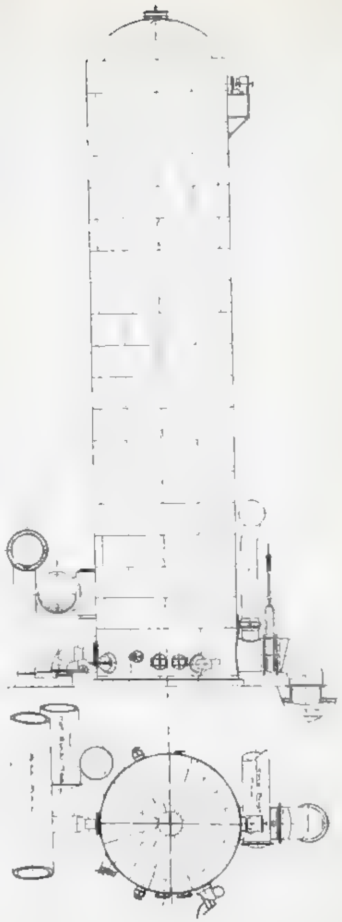


FIG. 19 STOVE COMPLETE WITH ALL CONNECTIONS.

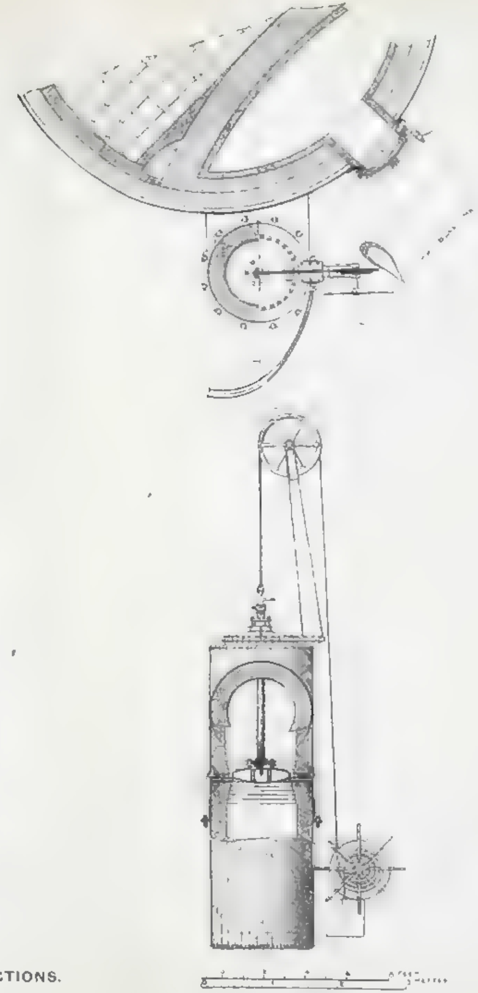


FIG. 20. 32' HOT-BLAST VALVE.

IS.

.. 18. 44″ X 84″ X 84″ X 66″

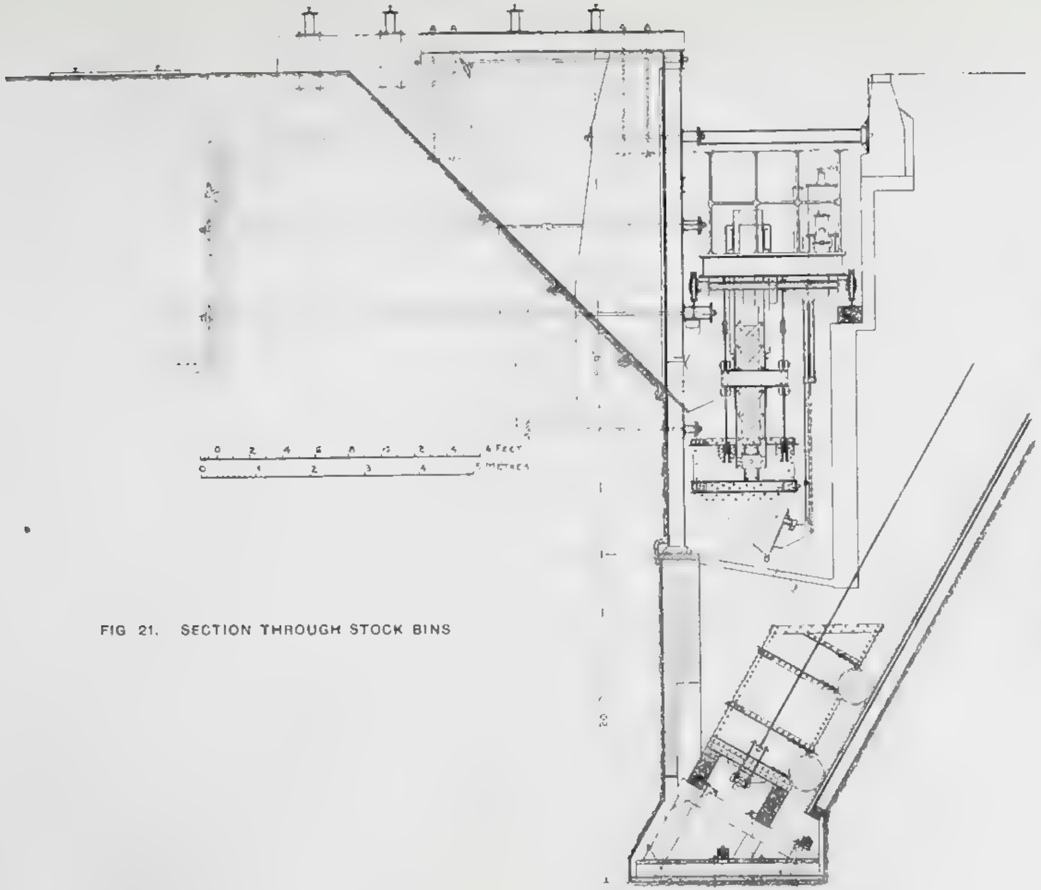


FIG 21. SECTION THROUGH STOCK BINS

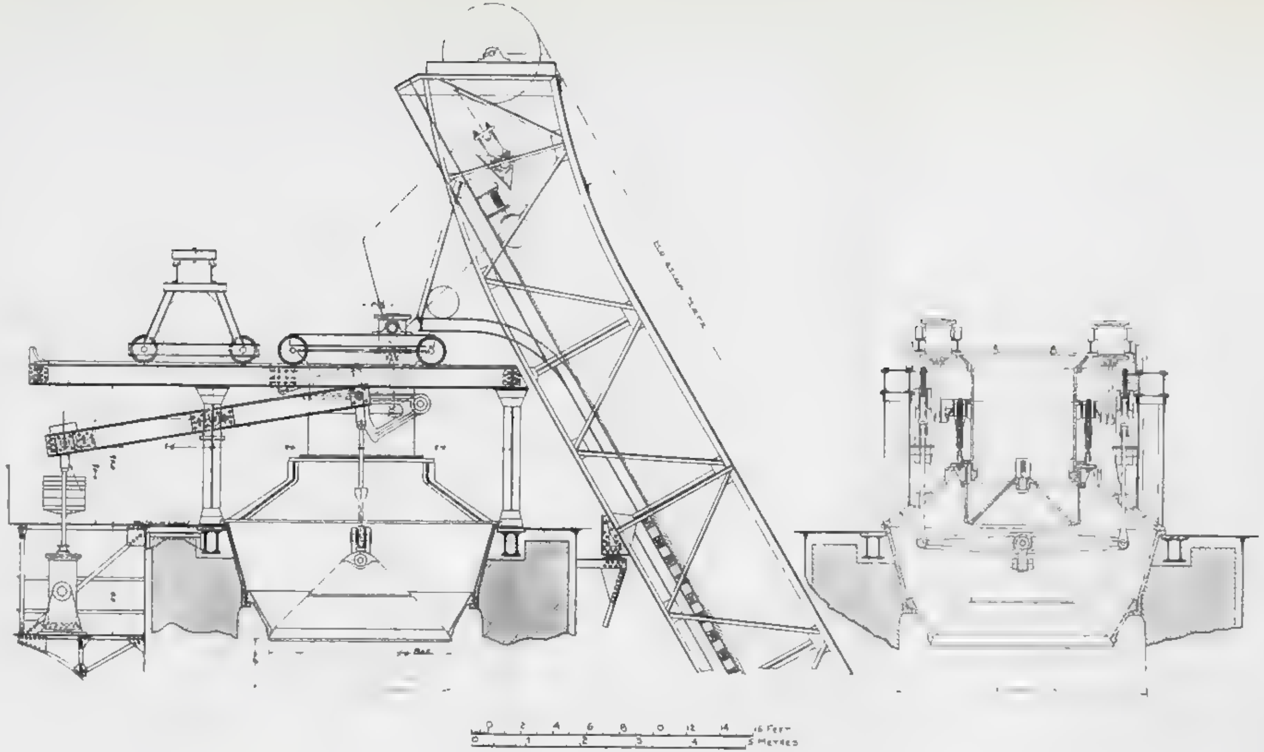


FIG. 22 FURNACE TOP.

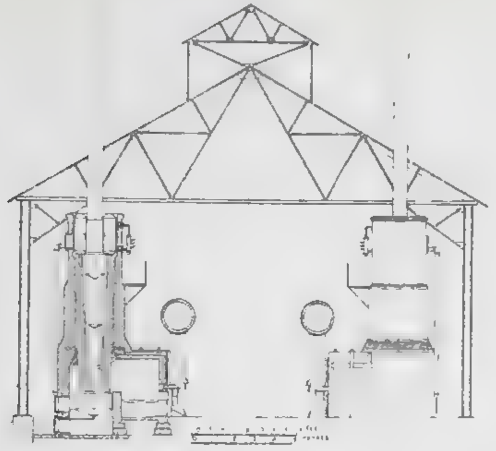


FIG 23. SECTION THROUGH BOILER HOUSE.

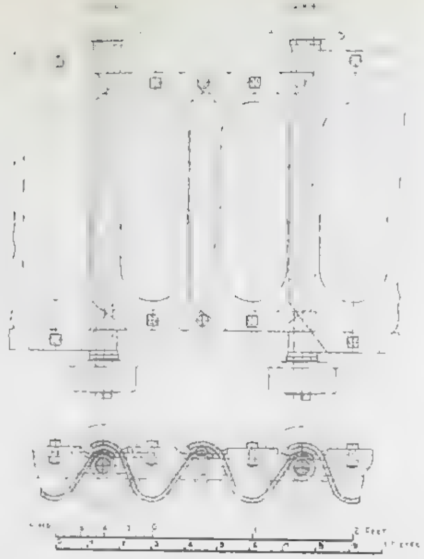


FIG. 25. CHILLS AND CHAINS FOR PIG-CASTING MACHINE.

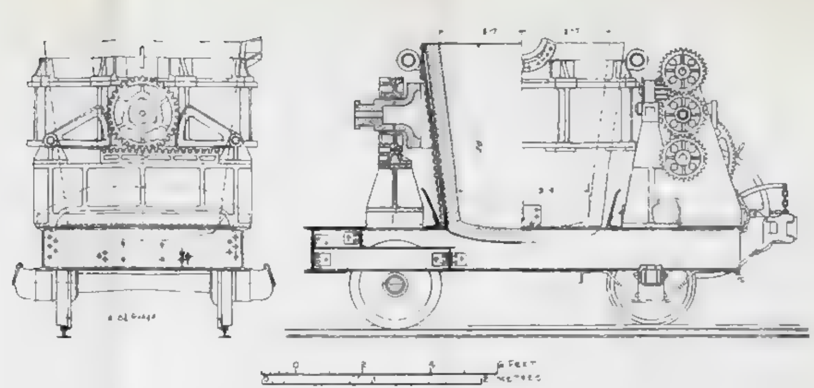


FIG 26 15-TON HOT-METAL LADLE CAR

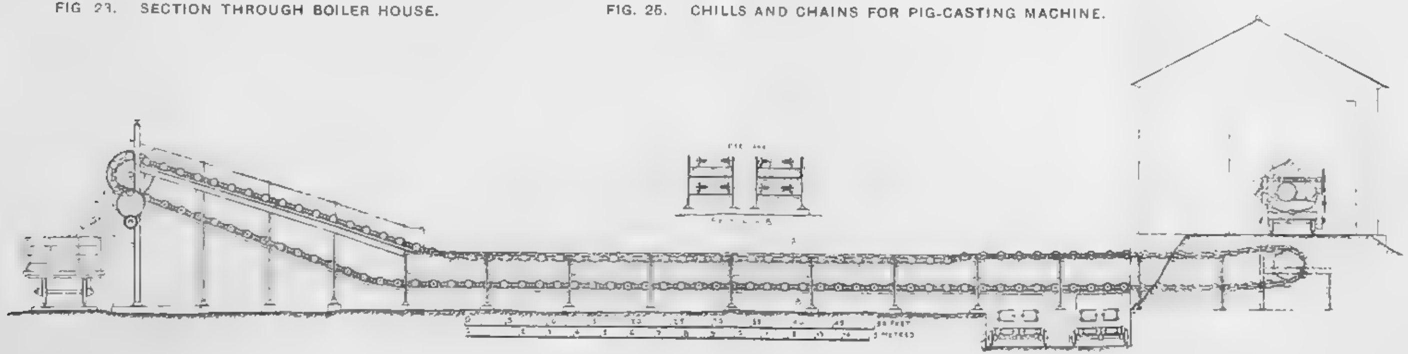


FIG. 24. PIG-CASTING MACHINE.

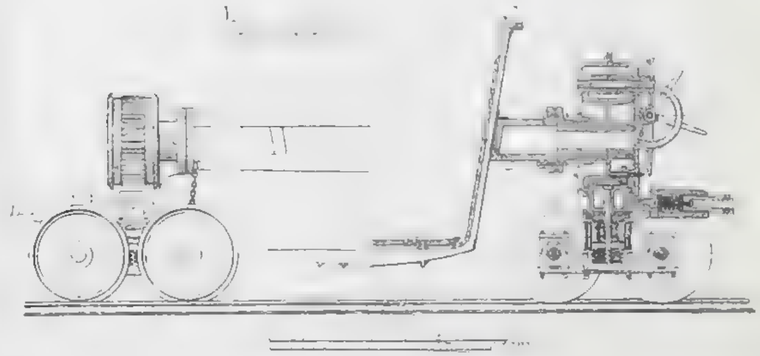


FIG. 27 200 CU. FT. CINDER LADLE CAR

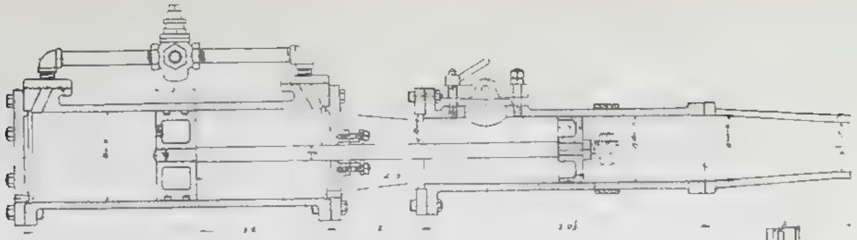


FIG. 28 TAPPING-HOLE GUN

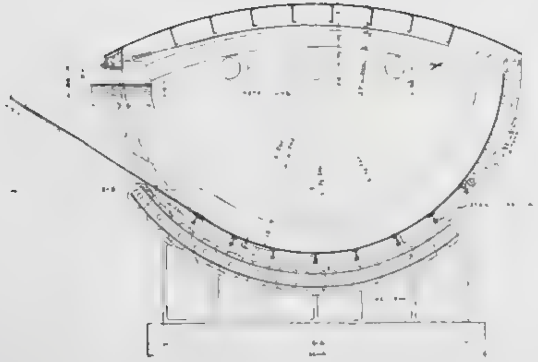


FIG. 29 300-TON HOT-METAL MIXER

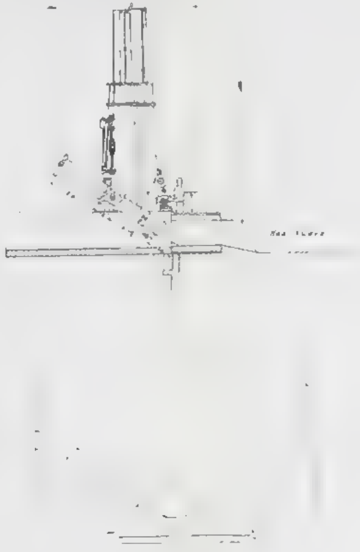


FIG. 32 STOCK PROFILES

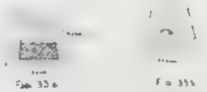


FIG. 33

EXPLOSION DOOR JOINTS

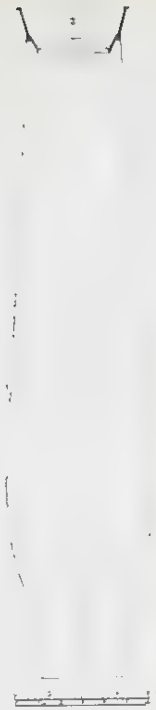


FIG. 30

LINES OF FURNACE No. 1

AFTER BLOWING OUT.

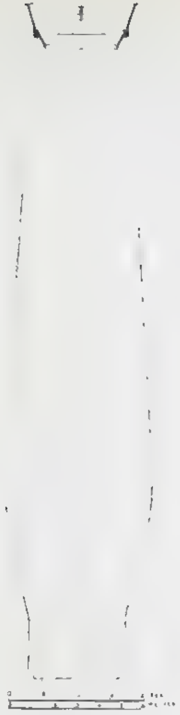


FIG. 31

LINES OF FURNACE No. 2

AFTER BLOWING OUT.

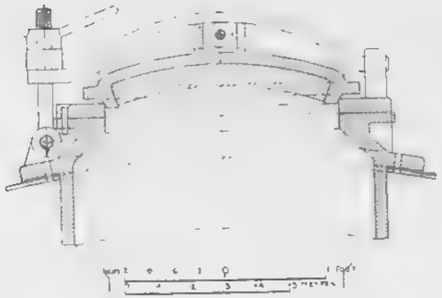
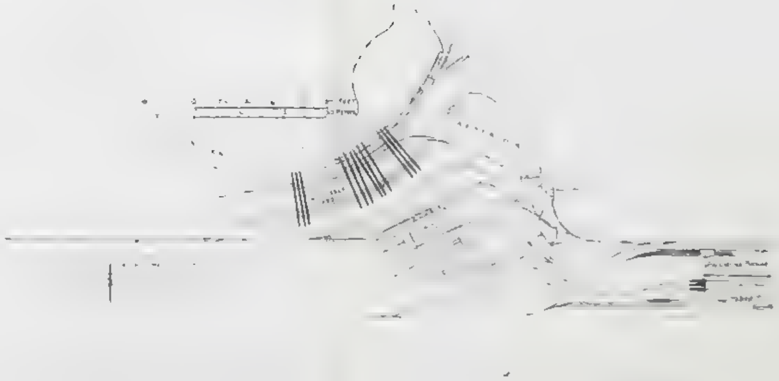


FIG 34 GAS-OPENING DOOR

FIG 35. PLAN OF FURNACE YARD.




PIG CASTING MACHINE

OBITUARY.

George W. Percy.

By the sudden and lamentable death of our highly esteemed President, on Friday, December 14, 1900, the Technical Society, and indeed the entire community, sustained an irreparable loss.

George Washington Percy was born at Bath, in the State of Maine, on July 5, 1847, his early youth being spent amid agricultural surroundings. He received his education as a boy at the Kent's Hill Academy, in his native State. It was during the progress of the Civil War that he found employment in the mercantile marine of this country. At this time he made a voyage to Europe, and also visited other countries.

Endowed with a natural aptitude for mechanical and mathematical pursuits, he decided about this time to study architecture, with a view to adopting it as his life profession. How wisely his choice was made is exemplified by the many structures which will stand for ages as monuments of his professional skill and intelligence.

His technical education was commenced in the office of Mr. Fassett, of Portland, Maine, and for some years his time was spent in faithful and painstaking study in qualifying himself for practicing the profession of his choice. Subsequently Mr. Percy entered the office of Bradley & Winslow, architects, of Boston, Massachusetts, and while there superintended several important works.

Coming to California in 1869, he settled in Stockton, returning to the East in September, 1871, immediately after the great Chicago fire, in which city he did some heavy work during the rebuilding operations, after which we once again find him located in Boston. Among other works with which Mr. Percy was associated in this latter city is the Equitable Life Insurance Building, a typical example of the class of work in which he took a special interest.

Returning once more to California, in 1876, and locating in San Francisco, still full of youth and energy, he immediately commenced to build up a successful and steadily increasing practice. Numerous important buildings in San Francisco and throughout the Pacific coast will testify for many generations to his professional ability and constructive knowledge. It is perhaps unnecessary to do more than mention the following as being among the more important of Mr. Percy's works: Stockton Insane Asylum, Stanford University library and assembly hall, girl's dormitory, Stanford University, Academy of Sciences Building, Market, near

Fifth street; Alameda city hall, Nevada State University, Reno, Nevada; Episcopal church, Stockton; Alvinza Hayward residence, San Mateo; Leland Stanford, Jr., museum, Palo Alto; Crassley dome and professors' homes, Mt. Hamilton; Methodist Episcopal church business building, Alameda; California School of Mechanical Arts, Sixteenth and Utah streets; San Joaquin county almshouse; De Fremery block, Oakland; children's house and playground and other buildings in G. G. Park; Strathmore apartment house, Larkin street; First Unitarian church, Geary and Franklin streets; Golden Gate Park panorama, Strawberry Hill; City Front Stables, Clay, near East street; John Benson office building, Leidesdorff and Pine streets; Hobart Building, Post street; the "Hobart" vault, Cypress Lawn Cemetery; Hoit's School, Menlo Park; the Bourn tomb, Laurel Hill Cemetery; Wells Fargo Building, Mission and Second streets; Alexander Young business block, Honolulu; Hayward Building, California and Montgomery streets.

In 1881 Mr. Percy traveled in Europe for pleasure and to study ancient and modern work, being especially interested in the archæological remains of Rome of all ages. Indeed, his continued study and interest regarding ancient Rome in all its phases was maintained to the last, and probably few persons were better informed than he was concerning the materials and constructive methods of the Romans.

In addition to filling the presidential chair of the Technical Society, in which he took the warmest interest, Mr. Percy was an active associate member of the American Institute of Architects; also a trustee of the San Francisco chapter, American Institute of Architects, and also a member of the Pacific Lodge of Free and Accepted Masons. He was a member of the Berkeley Literary and Professional Club; also of the Astronomical Society of the Pacific Coast, and was an amateur astronomer of no small ability. He was the author of many instructive technical papers, which he read before the societies in which he took so deep an interest. His interest in young students of architecture was often manifested, many of whom applied to him for advice and assistance in their studies, and never in vain. His skill and experience has also been frequently sought in consultations involving questions concerning architecture and construction. Among many such cases may be mentioned the fact that he was invited to act as consulting architect in connection with the new Union Depot and ferry building of this city. Indeed, it may justly be said of him that he was at the very zenith of a successful career, and that he not only occupied a high and honorable position among the members of his own profession,

but also enjoyed the absolute and perfect confidence of his many clients.

Among contractors and business men with whom he was brought into contact in the construction of his buildings he was most highly respected, and invariably regarded by them as being absolutely fair and just in his requirements, dispensing equal justice to contractors and owners alike without fear and without favor.

A widow and four children—two sons and two daughters—are left to mourn the loss of a devoted husband and a loving father.

Mr. Percy possessed an exceedingly strong personality. His wide capability, his sterling integrity and earnestness and, above all, his absolute thoroughness were apparent in everything he undertook. These moral qualities and the knowledge that he was in every sense a manly man, as well as a genial gentleman, will ever be associated with the memory of our late fellow-member and friend.

G. Alexander Wright, *Committee.*

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis,

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and the transactions of the participating Societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each Society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each Society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a Chairman and Secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transactions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the JOURNAL OF THE ASSOCIATION.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a com-

pensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the Chairman for counter-signature He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each Society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each Society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any Society may be used as it shall see fit. Payments by each Society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any Society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any Society may, at the pleasure of the Board, be excluded from this Association for non-payment of dues after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating Societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall shall have been ratified by three Societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several Societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following Societies have since certified their acceptance of the articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.
Technical Society of the Pacific Coast, March 1, 1895.
Detroit Engineering Society, January, 1897.
Engineers' Society of Western New York, January, 1898.
Louisiana Engineering Society, September 15, 1898.
Engineers' Club of Cincinnati, January, 1899.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

The Western Society of Engineers withdrew in December, 1895.

The Engineers' Club of Kansas City disbanded at the close of 1896.

The Denver Society of Civil Engineers and the Association of Engineers of Virginia disbanded in 1898.

Annual Report of the Chairman of the Board of Managers.

DECEMBER 31, 1900.

To the Members of the Board of Managers of the Association of Engineering Societies:

GENTLEMEN:—I have the honor to transmit to you and to the Association through you, the annual report of the Secretary of the Association for the year 1900. This shows an increase in membership during the year from 1475 in 1899 to 1541, while the number of the societies has not changed.

There has been a slight increase in the cost of the JOURNAL, as shown by the Secretary's report, causing a diminution in the net assets from those of 1899. The character of the JOURNAL is such that there should be no difficulty in making it self-sustaining, and the attention of the members of the Association is called to the fact that our JOURNAL has a circulation of about 1900 copies, and the advantages of advertising in such a journal will be evident to all.

In the report of the Chairman for 1899 he stated that no Engineer could afford to be without the JOURNAL. I desire to repeat that statement, and ask the members of the Association to keep this JOURNAL before their friends, with a view to inducing them to subscribe to it.

I also desire to call your attention to the able and efficient work of the Secretary, who does all the business of the Association, and gives a great amount of time and care to the work. It is desirable that the members of the Association should make every effort to secure advertisements for the JOURNAL among the members of the societies which they represent.

Respectfully submitted,

JAMES RITCHIE, *Chairman.*

Annual Report of the Secretary of the Board of Managers.

PHILADELPHIA, December 31, 1900.

Mr. James Ritchie, Chairman,

305 City Hall, Cleveland, O.

DEAR SIR:—I have the honor to present the following report upon the operations of the Secretary's office during the year 1900, and of the condition of the Association at the present time.

These data are concisely stated in the following statistical appendices:

A. Statement of receipts and expenditures during 1900.

B. Estimate of assets and liabilities at the close of 1900.

C. Detailed statement of cost of JOURNAL during 1900, by months.

D. Comparison of mailing lists of the JOURNAL at the close of 1899 and of 1900, respectively.

E. Statement of material in JOURNAL during 1900, by pages.

F. Comparison of conditions, 1894 to 1900, inclusive.

A study of Appendix F shows an increase in the cost of the JOURNAL, with a corresponding diminution of net assets, due partly to a sharp advance in the printers' rates and partly to an increase of 18 per cent. in the amount of matter published. The close of the year, nevertheless, finds us with a cash balance in hand of $1448.24, and total net assets of $2165.67.

During the year, no new societies have joined the Association, but the aggregate membership of our societies shows an increase of about 4½ per cent. The present aggregate of 1541 members is greater than at any time during the history of the Association, exceeding, as it does, by about 4½ per cent., the aggregate membership at the close of 1895, before the withdrawal of the Western Society of Engineers.

In my report for 1899 I was obliged to call attention to "a decided falling off in the amount of material presented for publication in the JOURNAL," the number of pages per thousand members having fallen to 369, the lowest reached during the preceding six years.

This condition has been, to a great extent, remedied during 1900; the number of pages of papers having increased from 958 in 1899, to 1130 in 1900, and the total per thousand members having increased to 432.

The close of the year finds us with considerable material on hand awaiting the January JOURNAL.

In my last annual report I called attention to the commendable activity of the Cleveland Society in obtaining advertisements for the JOURNAL, that society having, by means of the commission of 90 per cent. allowed by the Association, relieved itself entirely of charges on account of the Association JOURNAL.

At this writing the Engineers' Club of St. Louis is taking measures to follow the example of the Cleveland Society.

The List of Members of the Societies in the Association, first published in the JOURNAL for January 1899, and again in that for January 1900, now appears for the third time, and with further improvements in the matter of its typography.

Respectfully submitted,

JOHN C. TRAUTWINE, JR., *Secretary.*

APPENDIX A.

Statement of Receipts and Expenditures during 1900.

CASH, 1900.

Dr.

To Balance, January 1, 1900		$1,866 34	
" Assessments, at $2.00 per member:			
Boston Society of Civil Engineers	$992 00		
Civil Engineers' Club of Cleveland	387 50		
Engineers' Club of St. Louis	407 00		
Civil Engineers' Club of St. Paul	58 00		
Engineers' Club of Minneapolis	28 50		
Montana Society of Engineers	168 00		
Detroit Engineering Society	171 00		
Engineers' Society of Western New York,	83 00		
Louisiana Engineering Society	120 00		
Engineers' Club of Cincinnati	179 00		
Technical Society of the Pacific Coast	288 50		
		2,882 50	
To Subscriptions		768 94	
" Sales of Journal		181 92	
" " " Descriptive Index		26 50	
" Advertisements		370 83	
" Sales of reprints		104 25	
" Interest on deposits		16 44	
" Electros		25 25	
" Letter-heads		6 25	
" Copyright fee		1 00	
" Illustrations furnished to authors, etc		65 17	
" 792 misdirected envelopes sold		15 84	
			$6,331 23

Cr.

By Patterson & White Co. (Printers)	$3,523 15	
" Illustrations	558 10	
" Secretary's salary	600 00	
" Car fares	30	
" Discounts on subscriptions	28 85	
" " " sales	2 20	
" Messenger service	4 42	
" Stationery	17 40	
" Telegrams	9 46	
" Postage stamps	34 32	
" Express charges	2 55	
" Back numbers bought	50	
" Binding Journals for Paris Exposition	8 50	
" Civil Engineers' Club of Cleveland. Amount due from advertisement	16 20	
" Prof. Geo. D. Shepardson, expenses as chairman	5 00	
" Engineers' Club of St. Louis, credit balance at end of 1899	9 50	
Forward	$4,820 45	$6,331 23

Forward	$4,820 45	$6,331 23
By Secretary's trip to Boston, Feb. 6	21 10	
" " trip to New York, March 9	4 00	
" Copyright fee	1 00	
" Subscriptions refunded	5 50	
" Amount overpaid on subscription, refunded	2 00	
" Advertising, including cost of cuts ($24.80)	28 94	
		4,882 99
" Cash balance, December 31, 1900		$1,448 24

APPENDIX B.

Estimate of Assets and Liabilities at the Close of 1900.

AVAILABLE ASSETS.

Cash balance, December 31, 1900		$1,448 24	
Less subscriptions for 1901, paid during 1900		53 00	
			$1,395 24
Amounts receivable from Societies (for assessments, etc.):			
Boston Society of Civil Engineers	$38 20		
Montana Society of Engineers	130 00		
Detroit Engineering Society	47 50		
Engineers' Society of Western New York,	34 55		
		$250 25	
Subscriptions due:			
For 1900	90 00		
" 1899	100 80		
" 1898 and earlier	192 00		
		382 80	
For reprints		109 60	
" Advertisements		306 33	
" Sales of Journals		22 50	
" " " Index		7 25	
" " " Cuts		2 75	
			$1,081 48
			$2,476 72

LIABILITIES.

Patterson & White Co. (Printers):			
For December Journal	$168 50		
" Reprints	7 00		
		$175 50	
Civil Engineers' Club of Cleveland, commissions on advertisements		$108 90	
Engineers' Society of Western New York		70	
Illustrations		25 95	
			311 05
Net Assets			$2,165 67

APPENDIX C.

Detailed Statement of Cost of Journal during 1900, by Months.

	1	2	3	4	5	6	7	8	9	10	11	12	13
	Composition.	Paper, Presswork, Binding.	Wrapping, etc.	Postage.	Printer. Sum of 1, 2, 3 and 4.	Illustrations.*	Cost of Manufact'e Sum of 1, 2, 6.	Wrappers.	Secy's Salary.	Sundries.†	Total. Sum of 5, 6, 8, 9, 10.	No. of Pages.‡	Cost per Page.‡
January	$284 41	$278 25	$6 39	$18 06	$587 11	$147 35	$710 01	$5 50	$50 00	$47 23	$837 19	214	$3 91
February	98 91	131 25	6 01	10 60	246 77	32 50	262 66	4 75	50 00	26 36	360 38	108	3 34
March	71 78	103 25	7 25	7 75	190 03	19 84	194 87	4 75	50 00	66 96	331 58	88	3 77
April	78 60	95 25	6 33	8 81	188 99	98 15	272 00	4 75	50 00	36 92	378 81	84	4 51
May	78 48	117 15	6 69	9 03	211 35	94 05	289 68	5 00	50 00	39 74	400 14	90	4 45
June	70 07	105 00	4 77	8 05	187 89	....	175 07	4 75	50 00	44 39	287 03	80	3 59
July	112 23	119 40	4 77	8 21	244 61	87 85	319 48	4 75	50 00	7 93	395 14	94	4 20
August	42 15	86 75	4 40	8 62	141 92	9 00	137 90	4 75	50 00	4 65	210 32	64	3 29
September	89 82	101 15	4 70	7 73	203 40	26 50	217 47	4 75	50 00	3 61	288 26	78	3 70
October	90 47	101 15	4 84	7 97	204 43	33 50	225 12	4 75	50 00	8 24	300 92	78	3 86
November	97 75	122 50	4 57	8 40	233 52	27 08	247 33	4 75	50 00	4 55	319 90	84	3 81
December	56 35	95 50	5 38	6 52	163 75	15 00	166 85	4 75	50 00	8 36	241 86	68	3 55
Totals and averages	$1,171 02	$1,456 60	$66 40	$109 75	$2,803 77	$590 82	$3,218 44	$58 00	$600 00	$298 94	$4,351 53	1130	$3 85

*The figures in column 6 (Illustrations) include preparation of cuts and lithographic stones, and paper and presswork on insets.

†The figures in column 10 (Sundries) include all expenditures of the Association (such as stationery, postage, circulars, etc.) chargeable to the Journal and not embraced in any other column. They do not include the cost of preparing reprints of papers.

‡The figures in columns 12 (No. of Pages) and 13 (Cost per Page) include 4 cover pages in each number, and 16 pages in indexes to Vols. XXIV and XXV.

APPENDIX D.

Comparison of the mailing lists of the JOURNAL, at the close of 1899 and of 1900, respectively:

	1899.	1900.	Increase.	Decrease.
Boston Society of Civil Engineers	495	501	6	...
Engineers' Club of Cleveland	185	208	23	...
Engineers' Club of St. Louis	206	204	...	2
Civil Engineers' Society of St. Paul	29	29	...	...
Engineers' Club of Minneapolis	19	13	...	6
Montana Society of Engineers	107	109	2	...
Technical Society of the Pacific Coast	146	136	...	10
Detroit Engineering Society	97	105	8	...
Engineers' Society of Western New York	43	72	29	....
Louisiana Engineering Society	53	74	21	...
Engineers' Club of Cincinnati	95	90	...	5
In the societies composing the Association,	1475	1541	89	23
Net increase................66				
Extra copies to Societies	46	50	4	...
Advertisers	18	14	...	4
Exchanges	115	116	1	...
Subscribers	249	216	...	33
Complimentary copies	1	6	5	...
Totals	1904	1943	99	60
Net increase................34				

Besides this, many copies have been sold and specimen copies sent out; and authors of papers have each received five copies of the JOURNALS containing them. Two thousand five hundred copies of the January number were printed, 2100 of February, March and April, and 2250 of each of the other months.

APPENDIX E.

Statement of material in JOURNAL during 1900, by pages.

	Papers.	Proceedings.	Chairman's Report.	Advertisements.	Indexes to Vols.	List of Members.	Totals.	Cuts.	Plates and full-page cuts.
January	82	10	24	16		78	210	20	11
February	78	6		16		4	104	4	...
March	54	14		16			84	3	1
April	38	26		16			80	6	3
May	62	8		16			86	10	2
June	46	6		16	8		76	.....	...
July	66	8		16			90	9	4
August	42	2		16			60	5	1
September	52	8		14			74	9	...
October	56	4		14			74	21	2
November	58	6		16			80	18	2
December	32	9		15	8		64	7	1
Totals	666	107	24	187	16	82	1082	112	27
Covers							48		
Total							1130		

APPENDIX F.

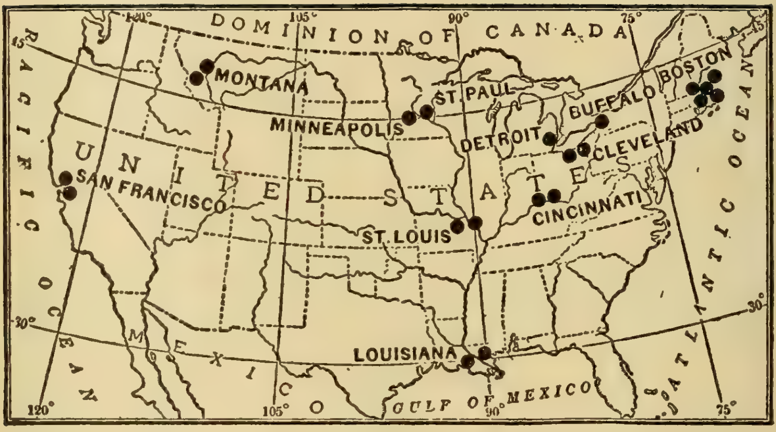
Comparison of Conditions, 1894 to 1900, Inclusive.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
							Pages of Papers.		Cost of Journal.*					Illustrations.			
Year.	Number of Societies in Association, Dec. 31.	Aggregate Membership of Societies, Dec. 31.	Subscribers, Dec. 31.	Exchanges, Dec. 31.	Net Receipts from Advertisements.	Total Number of Pages in Journal.	Total.	Per 1000 Members.	Total.	Per Page.	Per Member.	Per Member per 1000 pages.	Annual Assessment per Member.	Small Cuts.	Plates and Full-Page Cuts.	Cost.	Net Assets, Dec. 31.
1894	8	1174	176	110	$671 00	1290	653	556	$5774 59	$4 48	$4 92	$3 81	$3 00	86	54	$651 60	—$758 91‡
1895	11	1477	215	122	599 09	1482	792	536	5911 48	3 99	4 00	2 70	3 66	116	66	859 60	223 93
1896	9	1106	241	108	763 25	856	490	443	3928 42	4 59	3 55	4 15	3 00	62	56	771 39	1244 94
1897	10	1252	233	102	410 25	1016	638	510	3140 43	3 09	2 51	2 47	2 50	57	45	503 85	2562 04
1898	12	1370	246	114	465 58	1110	738	539	3462 08	3 12	2 53	2 28	2 00	166	42	729 38	2936 71
1899	11	1475	249	115	390 88	958	544	369	3233 44	3 38	2 19	2 29	2 00†	124	30	561 24	2442 70†
1900	11	1541	216	116	370 83	1130	666	432	4351 53	3 85	2 82	2 50	2 00	112	27	590 82	2162 67

*The publication of the Descriptive Index of Current Technical Literature was discontinued at the end of 1895.

†During 1899, with an assessment of $2.00 per member, the Association made a rebate of $1.00 per member for the purpose of reducing surplus, making the actual charge only $1.00 per member, and reducing the assessment by about $1400.

‡Deficit at close of 1894. Since then, each year has shown a surplus.



DOMINION OF CANADA
PACIFIC OCEAN
UNITED STATES
MONTANA
ST. PAUL
MINNEAPOLIS
DETROIT
BUFFALO
BOSTON
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
ATLANTIC OCEAN
MEXICO
LOUISIANA
GULF OF MEXICO
120°
105°
90°
75°
45°
30°

ASSOCIATION OF ENGINEERING SOCIETIES.

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BRICK AND CONCRETE-METAL CONSTRUCTION.

PAPERS PRESENTED AT THE MEETING OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, HELD OCTOBER 17, 1900.

Economy and Strength of Brick and Concrete Arches for Floor Systems of Highway Bridges.*

BY WILLIAM D. BULLOCK, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

THE Weybosset bridge in the city of Providence spans the Providence River at Market square. There are three piers dividing into four spans the river channel, which is 132½ feet wide. The channel at the bridge being on a curve the steel plate girders, which are 42½ inches deep, are placed on radial lines, Fig. 1.

Extending from girder to girder, and riveted to them, are transverse floor beams 2 feet deep and spaced 8½ feet apart. Supported on these floor beams are 10-inch I beams, spaced about 2 feet 5 inches apart in radial lines, between the main girders.

The spaces between the I beams and the main girders are covered by brick arches, leveled up with Portland cement concrete to within 2 inches of grade.

The area of the bridge is 31,610 square feet.

Located as this bridge is, in the center of the city and furnishing the main passageway between the east and west sides, it is subjected to very heavy and concentrated travel, including both highway and trolley car travel. Under these circumstances the question of designing a substantial floor at a reasonable cost became one of great importance.

*Manuscript received November 6, 1900.—Secretary, Ass'n of Eng. Socs.

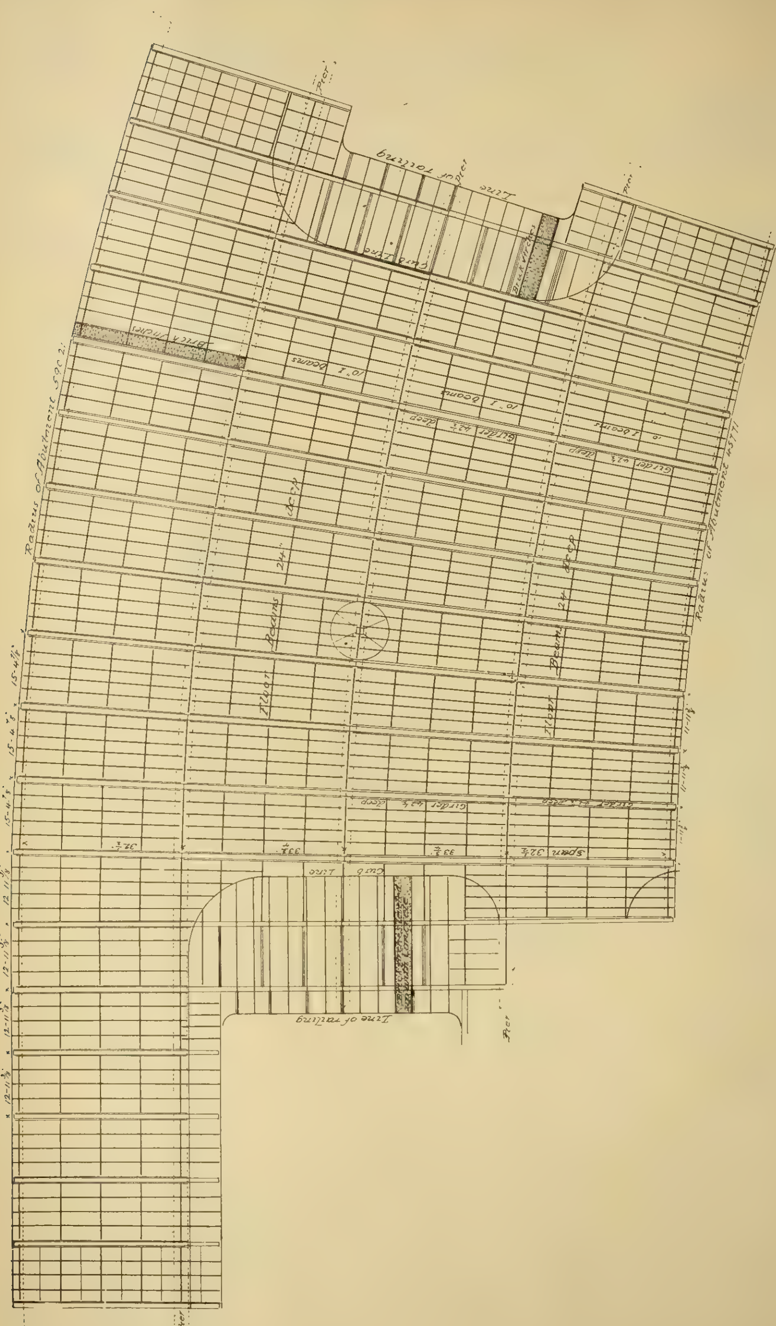


FIG. 1. FLOOR SYSTEM OF WEYBOSSET BRIDGE OVER PROVIDENCE RIVER.

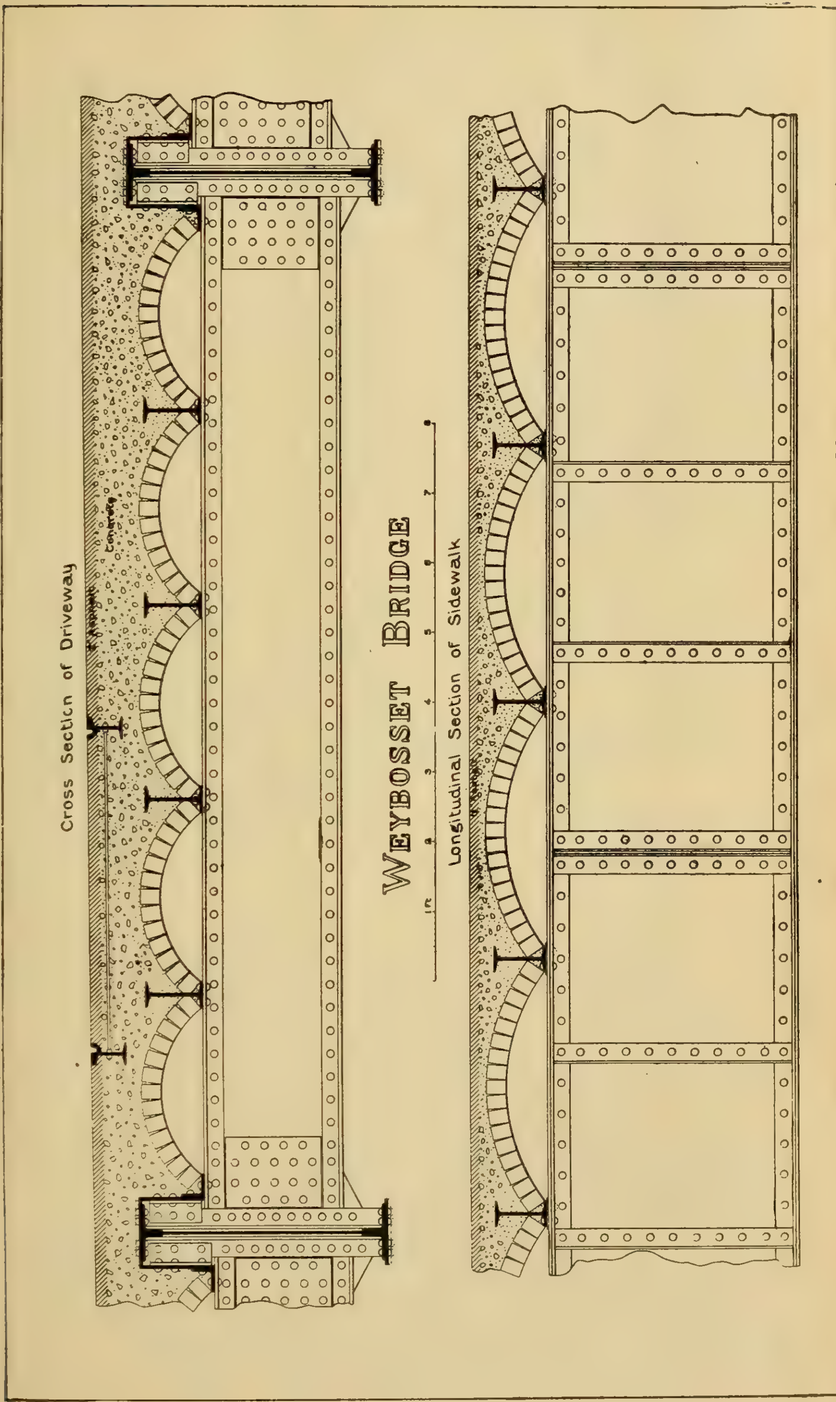

Cross Section of Driveway
Concrete
WEYBOSSET BRIDGE
Longitudinal Section of Sidewalk

FIG. 2.

The ordinary forms of flooring of steel shapes, at the price of 2.34 cents per pound paid for this bridge, would cost about 72 cents per square foot, and the concrete for leveling up ready to receive the asphalt paving would cost 15 cents per square foot, making a total cost of 87 cents per square foot for this form of construction at the former low price of steel. At the prevailing prices of steel during the past year, of say 5 cents per pound, the cost would be about $1.68 per square foot.

The cost of the steel 10-inch I beams and dam plates was 26 cents per square foot of floor, and the cost of the brick arches and concrete for leveling up to grade was 26 cents per square foot, making a total cost, for the masonry floor, of 52 cents per square foot. This shows a difference of 35 cents per square foot in favor of the masonry floor as compared with the low contract prices. In addition to the saving in the first cost of the masonry arch floor, there is an additional saving in the reduced surface of metal to be painted.

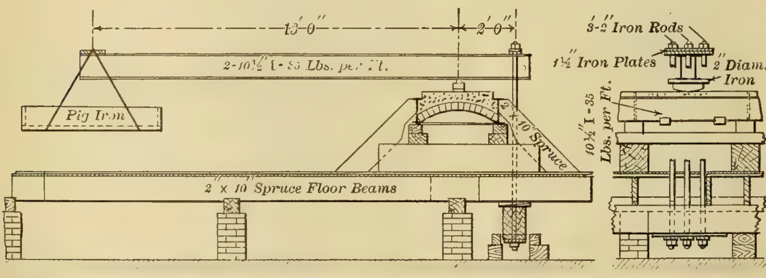


FIG. 3. TEST OF ARCHES PROPOSED FOR DRIVEWAY FLOOR OF THE WEYBOSSET BRIDGE.

The weight of the steel floor of Carnegie shapes leveled up with concrete would be about 112 pounds per square foot and that of the masonry floor 118 pounds per square foot.

After the plans were decided upon and the actual work of construction begun, it was decided to make the concrete $2\frac{3}{4}$ inches thicker, in order to enable the trolley company to use deeper rails than originally intended. This increased the weight $39\frac{1}{2}$ pounds and the cost 7 cents per square foot. Fig. 2 shows the section of the floor as actually constructed.

The question is thus narrowed down to whether or not a thin floor of masonry arches between steel I beams will have sufficient strength to meet the trying conditions of a city highway bridge. In addition to various calculations made to determine this question, it was thought desirable to make some prac-

Number of Experiment.	Brand of Cement and Proportions.		Rise of Arch in Inches.	Thickness at Crown in Inches.	Number of Days from Construction to Destruction.	Greatest Pressure per Sq. In. of Shoe on Concrete without Indication of Crushing.	Loading in Tons, when:			REMARKS.
	Brickwork.	Concrete.					Snapping Sound First Noticed.	Small Cracks Showing at Crown.	Arches Broken.	
1	Alpha 1–1	Atlas 1–2–4	6	7	8		33.3	16.5	34.0	Some yielding of tie bars, which probably hastened failure.
2	Alpha 1–1	Atlas 1–2–4	6	7	15		18.1	18.1	54.6	
3	Alpha 1–1	Atlas 1–2–4	6	7	22	2.9	45.6	17.7	60.6	
4	Alpha 1–1	Atlas 1–2–4	6	7	29	4.75	18.9	30.6	65.6	
5	Alpha 1–1	Atlas 1–2–4	6	7	57	3.8	48.2		75.9	Three trials: First interrupted by crippling of lever; second interrupted by failure of anchorage.
6	Alpha 1–1	Atlas 1–2–4	6	7	172	4.0	45.2	51.1	62.7	Slight yielding of tie bars.
7	Alpha 1–1	Alpha 1–2–4	7	5½	8	2.0	20.3	31.6	55.1	

tical tests on arches of the same dimensions and exactly of the same construction as those proposed to be used. In the city bridge shop 6 brick arches were built between 10-inch I beams, leveled up with concrete, and the I beams tied together with iron clamp bars. In the absence of any testing machine a contrivance was improvised from materials on hand for making the tests, substantially as shown by Fig. 3. The arches were made of partially vitrified paving brick made by the New England Brick Company and laid in Atlas Portland cement mortar, 1 to 1. The concrete was made of Atlas and Alpha Portland cement 1 part, sand 2 parts and screened medium gravel 4 parts. The Atlas cement, tested neat in briquettes at the end of 24 hours, showed a tensile strength of 426 pounds per square inch and the Alpha 365 pounds per square inch.

The voids in sand were 30.3 per cent. of volume.

The voids in gravel were 35.9 per cent. of volume.

The weight of the brick arches per cubic foot was 150.3 pounds and the concrete 158.1 pounds.

The foregoing table shows the results of the tests. The bearing shoe was of the same width and curvature as some of the heavy low gears in use in this city. The yielding of the heavy 4 x $\frac{7}{8}$-inch clamp bars in the first and sixth experiments showed that there was a large horizontal thrust from the arches.

A Test of the Strength of Rapp Floor Arches.*

By Frederic H. Fay, Member Boston Society of Civil Engineers.

From time to time the Engineering Department of the City of Boston has been asked by the Building Commissioner to make tests upon different types of fireproof floors. These tests, however, had nothing to do with fireproof qualities, they having been made solely to satisfy the Commissioner that the floors in question were capable of sustaining the load required by the city building laws. Hence we might call them tests of the "working strength." One of these, a test of some floor arches of the Rapp type of construction, is described herewith. Considering the fact that the test was made upon one of the floors of a building (which at the time was in process of construction), and that the arches had been built before the test was proposed, it is thought that the conditions found were those likely to be met in practice.

Details of this Rapp floor are shown in the accompanying figures.

Two adjoining arches near the center of the building were selected for the test, the span of each arch being, approximately, 7 feet 10¼ inches, and the width 16 feet 5 inches, the distances being measured between the centers of the supporting beams. The total area of the two is about 258 square feet.

The test consisted in loading the arches with a live load of about 500 pounds per square foot, the behavior of the arches during the test being studied by noting their deflection and spread.

CONSTRUCTION OF THE FLOOR.

Between columns 11 and 12 and columns 16 and 17 are two 18-inch I-beam headers. At right angles to the latter are three 15-inch I beams, the middle one being framed into the 18-inch beams and the other two connecting directly to the columns.

Curved Rapp tees are supported by the bottom flanges of the 15-inch beams. These tees consist of pieces of sheet steel 4½ inches wide and 1-16 inch thick, bent so as to form a "T" section with about 2¼-inch flange and 1½-inch stem. Separators, made by bending a strip of steel 1½ inches wide by 1-16 inch thick, regulate the spacing of the tees at about 8¾ inches on centers.

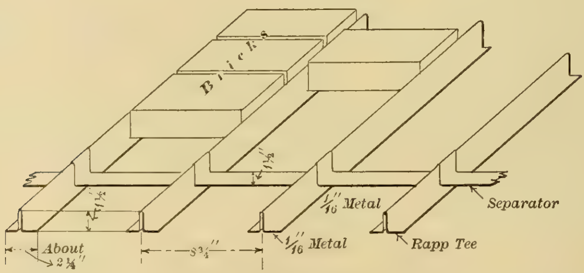
The Rapp tees being placed with their stems upward, the flanges are available for supporting rows of bricks which form an

*Manuscript received November 6, 1900.—Secretary, Ass'n of Eng. Socs.

arch of nearly 9 inches rise above the bottom of the beams. The bricks were laid dry, and after they were in place cement grouting was supposed to have been poured over the arch and into the joints between the bricks. Many of the joints, however, apparently contained but little mortar.

A filling of cinder concrete, said to be made of one part Atlas cement and eight parts cinders, was then deposited upon the arches to the level of the tops of the 15-inch beams. Thus there was about 4 inches of concrete above the brick arch at the crown, the depth increasing to a maximum of 12 inches of concrete at the springing. Neither the upper layer of concrete, inclosing the nailing strips, nor the wooden floor had been put in place at the time the test was made.

The 15-inch I beams were said to be connected by tie rods, which had been bent upward two inches or more out of line in order that they might not be exposed in the ceiling at the crown of the arch.



Details of Arch

DETAILS OF RAPP FLOOR IN BUILDING ON INDIA STREET.

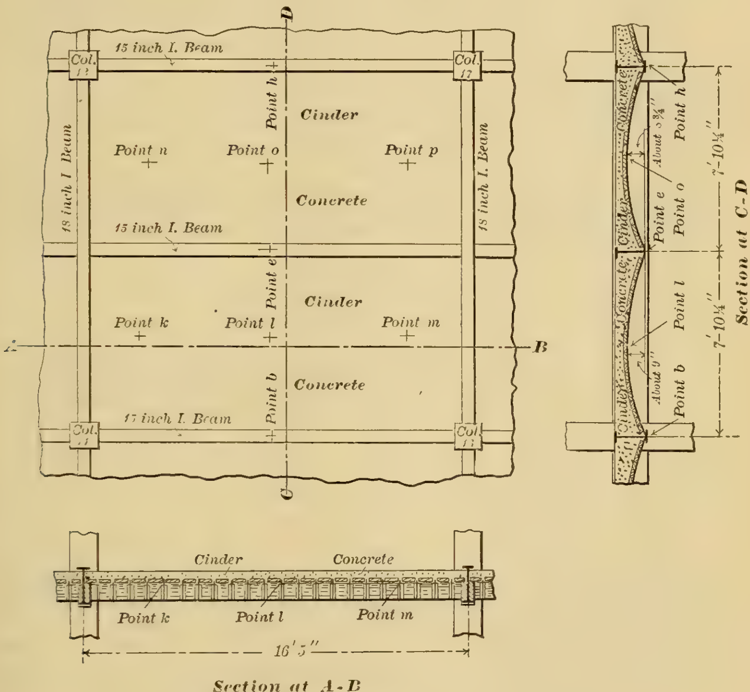
DETAILS OF THE TEST.

The test was begun Wednesday, November 9, and ended Saturday, November 12. When the arches received their full load the concrete filling had been in place fifteen days. The loading was made by using bricks carefully piled in such a manner as to avoid breaking joints, thus allowing their weight to be uniformly distributed. A representative of the building department supervised the loading, and by weighing and measuring several lots of bricks secured the data from which the total weight of bricks was estimated from their volume. The maximum load applied was, very closely, 500 pounds per square foot.

The deflection of the floor was obtained by taking levels upon the under side of the beams and arches of the two bays tested, and

also upon two of the adjoining arches. The spread of the arches was determined by measurements with a steel tape and an engineer's scale.

The first series of levels and measurements was made between 10 and 2 o'clock of Wednesday, November 9, before any live load was applied to the floor. From 2 o'clock of Wednesday until noon of Thursday workmen were engaged in putting on the bricks.



Partial Plan of Second Floor, Showing Tested Bays.

Friday morning, after the arches had been carrying their full live load for nearly twenty-four hours, the second series of readings was taken. Friday afternoon the load was entirely removed. After a period of rest of about sixteen hours the bays were again measured on Saturday morning, to determine to what extent the floor had recovered from the effects of the load.

Table I shows the deflections of the two arches tested. The deflections there given are *net*; that is, the total drops of the arches have been corrected to allow for the settlement of the supporting beams, so that the net results given are the same as though there had been no vertical movement of the arch supports.

TABLE I.

SHOWING DEFLECTION OF ARCHES.

POINT. [On Under Side of Arch].	DEFLECTION Under Live Load of 500 Lbs. per Sq. Ft.	UPWARD MOVEMENT Upon Removal of Load.	DEFLECTION Still Remaining after Removal of Load.
k	0.21 inch	0.11 inch	0.10 inch
l	0.26 "	0.14 "	0.12 "
m	0.24 "	0.16 "	0.08 "
n	0.18 "	0.13 "	0.05 "
o	0.30 "	0.19 "	0.11 "
p	0.22 "	0.16 "	0.06 "
Average for Arch **klm**	0.24 "	0.14 "	0.10 "
Average for Arch **nop**	0.23 "	0.16 "	0.07 "
Average for both arches	0.23 "	0.15 "	0.09 "

Measurements at the middle of the 15-inch beams showed the spread of the arches in the direction C D to be as given in Table II.

TABLE II.

SHOWING SPREAD OF ARCHES.

ARCH.	ELONGATION Under Live Load of 500 Lbs. per Sq. Ft.	CONTRACTION Upon Removal of Load.	ELONGATION Still Remaining after Removal of Load.
From **b** to **e**	0.16 inch	0.09 inch	0.07 inch
From **e** to **h**	0.09 "	0.07 "	0.02 "

Throughout the test levels were taken upon the two adjacent arches, at C and D, which were liable to deformation from the thrust of the loaded arches. No considerable movement was found in either adjacent arch, and apparently their shape was practically unchanged.

CONCLUSIONS.

Under the load of 500 pounds per square foot the average deflection of the two arches tested was $\frac{1}{4}$ inch. Sixteen hours after the removal of the load the arches had regained about 60 per cent. of their deflection, making the average deflection still remaining less than $\frac{1}{8}$ inch. Some permanent set might have been expected, due to the closing of certain joints between bricks which were only partly filled with cement grout. Still, it is possible that the arches had not entirely recovered from their fatigue, and that a further slight upward movement could have been detected had readings been taken at a longer interval after the removal of the load. The smallness of the spread of the arches was probably due to the fact

that the floor had been built in the adjoining bays, and its stiffness was sufficient to prevent much sidewise motion of the arches in question. It is not likely that the bent tie rods would be very efficient in holding the thrust, which must have been resisted principally by the sidewise bending of the supporting beams and outer walls. The practice of bending tie rods in arches is certainly not to be recommended, and it is understood that, in accordance with the suggestion of the Building Department, the rods of the other floors of this building have been made straight.

Expanded Metal as Used in Fireproof Building Construction and Other Work.*

By William M. Bailey, Member Boston Society of Civil Engineers.

The object of this paper is to give briefly some information regarding the uses of expanded metal, and the results of a few tests made on expanded metal and concrete structures.

At intervals there have been submitted for the consideration of engineers and architects different combinations of plastic materials and steel, and of concrete and steel, with the steel in the form of isolated ribs acting entirely in tension; combinations where single rods are imbedded in the tension side of the concrete, and combinations of steel and concrete where the steel in continuous sheets is imbedded in the tension side of the concrete and acts also under transverse stress. Each of these methods claims to possess certain advantages. The expanded metal system belongs to the latter class, in which the expanded metal acts entirely in tension and is distributed through the tension side of the slab or beam. The metal should be placed as far as possible from the neutral axis where its moment of resistance is greatest, and at the same time be thoroughly imbedded in the concrete. In order to develop the full strength of steel it is also necessary that it should be held in place by some means possessing greater strength than the cohesion between the steel and the concrete.

Expanded metal is made from sheet steel cut with the grain, and expanded into diamond-shaped meshes, greatly increasing the original size of the sheet without any waste of material. Expanded metal lathing is made from the lighter gages of steel, Nos. 27 and 24, and is expanded only about three times the size of the sheet of steel. This lathing, besides being substituted for wooden laths, is use in the construction of fireproof partitions and outside walls. It is also almost exclusively used for the framing of cornice and ornamental plaster work. The metal generally used in floors is No. 10 or No. 4 gage, the short diameter of the diamond mesh being 3 and 6 inches respectively, making the finished product from eight to twelve times wider than the sheet of steel. This gives for each foot in width a sectional area of .168 square inch for the 3-inch mesh, No. 10 gage, and .282 square inch for the 6-inch mesh, No. 4 gage metal.

For fireproof floors cinder concrete is largely used, on account of its lightness and its great resistance to fire. Tests show that it

*Manuscript received January 2, 1901.—Secretary, Ass'n of Eng. Socs.

is superior to either stone concrete, tile or brick work laid in Portland cement mortar. It weighs 100 pounds per cubic foot, and has an average crushing strength of 1200 pounds per square inch, mixed in the proportion of one part cement, two parts sand and five parts cinders. Where we require greater strength Portland

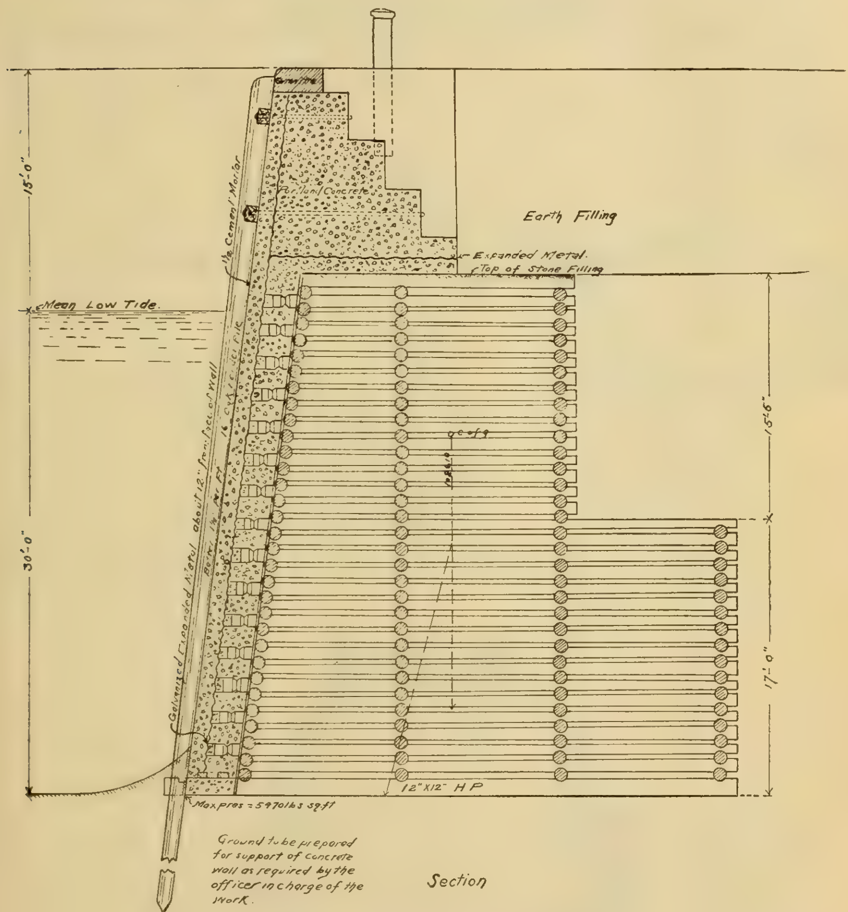


FIG. I. RETAINING WALL AT THE NEW DOCK FOR THE JOINT USE OF THE F. R. R. CO. AND THE UNITED STATES NAVY YARD, BOSTON, MASS., SHOWING THE USE OF CONCRETE AND EXPANDED METAL.

cement stone concrete is used with heavy expanded metal. For this construction tight wood centering is put up between floor beams so that the concrete can be properly tamped, and the expanded metal is placed directly on the centers. The shape of the metal is such that it touches the centering at only one point in each

mesh, which allows space for the concrete to be worked in and around the meshes, thoroughly imbedding the metal. In joining one sheet of metal with another it is necessary only to lap the sheets

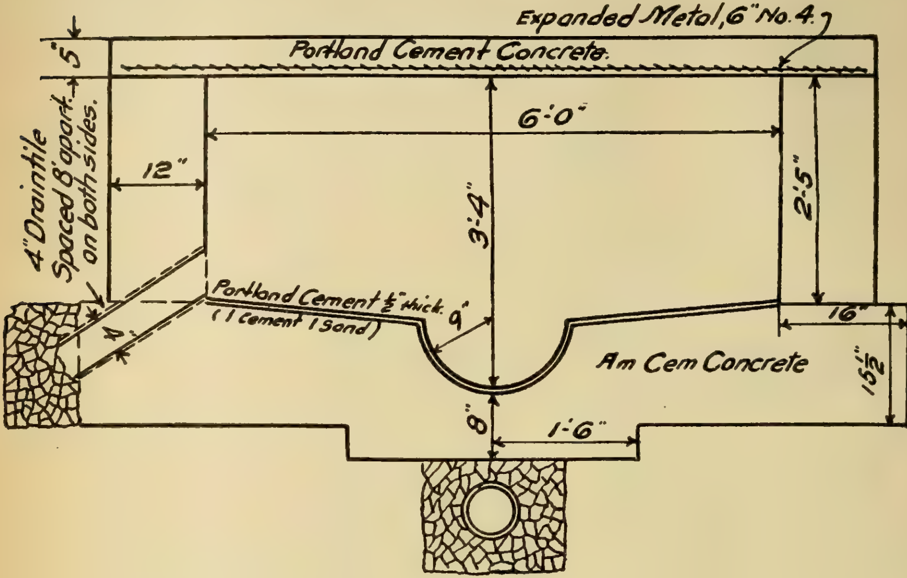


FIG. 2. COVERED WATERWAY.

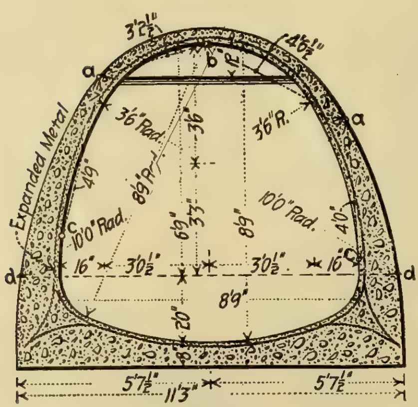


Fig. 3.

SECTION OF PROPOSED CONDUIT FOR NEW JERSEY WATER CO.

from 6 to 12 inches, and the concrete will bond them together so securely that the metal will break before they can be pulled apart. The shape of expanded metal is such that it cannot slip or be pulled through the concrete. Concrete and metal have to work together;

no sudden shock or continued vibrations can break their bonds. A great advantage in expanded metal is that it gives tensile strength not only lengthwise, but also transversely. It forms a blanket system, distributing the load in all directions, the whole acting as a monolithic structure.

When steel is properly imbedded in Portland cement concrete or plaster, we may feel sure that it will not rust. The expansion and contraction of steel caused by changes in temperature is practically the same as that of concrete. Combined in one structure,

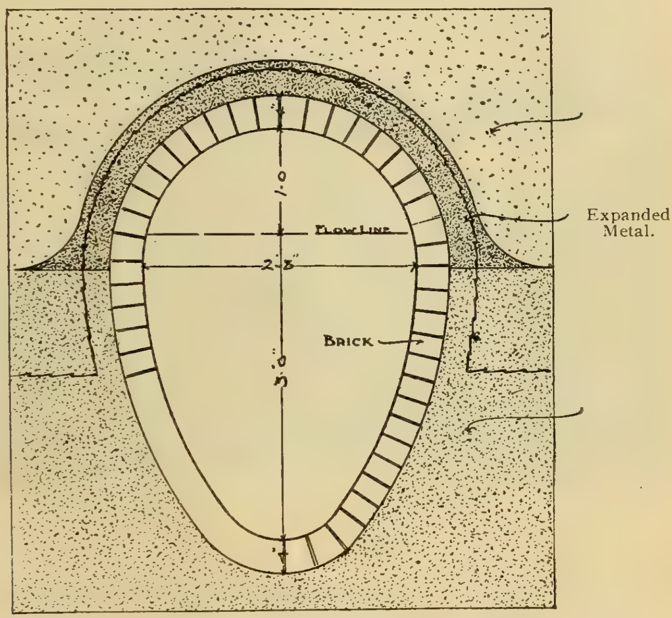


FIG. 4. EXPANDED METAL AS USED TO REINFORCE ARCH OF SEWER.

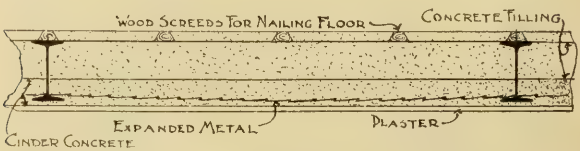
steel and concrete act so well that the expanded metal system has a wide field, and it is interesting to note the different designs where expanded metal can be used with a saving of material.

The walls of wooden and steel frame buildings are built of 2 inches of Portland cement and expanded metal lath. Large tanks and cisterns have been built with expanded metal and concrete. Sidewalks, floors and highway bridges, foundations in quicksand, conduits and sewers, coverings for reservoirs, flat arches and many other designs can be successfully built with this construction, and money saved by so doing.

The question arises, How much does expanded metal increase the strength of a concrete structure? Where crushing strength

only is required expanded metal does not add materially to the strength of the concrete, but in any structure that is subject partly to tensile strain expanded metal may be used with great advantage to develop the full compressive strength of the concrete. Load a concrete beam, for example. It gives way when the ultimate tensile strength is reached, which is possibly one-eighth of the com-

FIG. 5. LOAD SECTION OF CULVERT.



№ 8 SYSTEM

FIG. 6.

pressive strength of the same material. If by the introduction of a light rod or sheet of expanded metal we can make the beam stand until the ultimate crushing strength is reached, we have increased the strength of the beam at least eight times.

I will give the results of a few tests of the expanded metal system, that will prove all we can say for the strength of the combination. In most of these tests on flat floor slabs, tabulated below, the spans are short, but it is only a question of greater thickness of

concrete and heavier metal for equal strength on longer spans; and formulæ are now in use by which we design the composite structure with the same confidence that we have in designing wooden or steel structures.

TESTS OF CONCRETE AND EXPANDED METAL FLOORS. FLAT SLABS, SUPPORTED ON I BEAMS.

No. of Test.	Span.	Thickness.	Mixture of Concrete. C.	Sand.	Cinders.	Days Old.	Equiv. Dist. Load per Sq. Ft.	Deflection.	Size of Metal.	REMARKS.
1	4′ 1½″	3″	1	2	5	30	2333		3″ Mesh. No. 10 Gage.	Cement used in all these tests was American Portland.
2	4′ 1½″	3″	1	2	5	31	2354		"	Test made on same slab as above.
3	5′ 2″	3½″	1	3	6	30	775	$\frac{1}{16}$″	"	
4	4′ 0″	3½″	1	2½	5	30	1750	None	"	
5	6′ 0″	3½″	1	2	5	30	1100	¼″	"	
6	6′ 0″	4″	1	2	Rock. 6	28	850	$\frac{1}{16}$″	"	This floor had 1″ granolithic finish.
7	5′ 4″	4″	1	3	6	30	914	$\frac{5}{16}$″	"	
8	5′ 4″	6″	1	3	6	30	914	None	"	
9	11′ 0″	6″	1	2	5	30	360	$\frac{9}{64}$″	2 Sheets. 3″ No. 10.	When load was removed, $\frac{3}{64}$″ deflection remained.
10	4′ 0″	2½″				30	26	Broke	No Metal.	
11	4′ 0″	2½″				30	256	"	3″ Mesh. No. 10 Gage.	

DESCRIPTION OF TESTS.

Test No. 1. The slab tested was a panel selected from floors built in an eight-story building. The mixture of the concrete was one part Alpha cement, two parts sand and five parts cinders, and when tested was thirty days old. In section it was like Fig. 8. The I beams supporting the slab were 4 feet 1½ inches on centers; thickness of concrete 3 inches, with one sheet 3-inch mesh, No. 10 gage, expanded metal imbedded in the lower part. The testing began by loading a platform 4 x 12 feet with pig iron. No deflection was perceptible until 13 tons had been put on, when there was a deflection of $\frac{1}{32}$ inch. It then increased under the loading as follows:

Tons.	Deflection.
17½	3/32 in.
20	1/8 "
25	3/16 "
30	1/4 "
35	5/16 "
44½	3/8 "
48	9/16 "
58⅛	11/16 "

After twenty-four hours the load was removed and the floor returned to its original position, which shows considerable elasticity of the combination.

Test No. 2. This test was made the following day on the same slab as test No. 1 by loading a plank 12 inches wide, 9 feet 6 inches long, placed lengthwise in the middle of the bay. A total load of 23 tons was applied, with a deflection of $\frac{5}{8}$ inch. The slab gradually settled down and broke, resting on a false floor which had been placed 3 inches below. A final test on this slab was made by dropping a weight of 185 pounds (18 inches square on the end) 11 feet upon the broken slab, after the false floor had been removed, without apparently doing further damage. This floor was designed to carry a breaking load of 1600 pounds per square foot, and the tests showed over 40 per cent. increase of strength.

All of the tests tabulated, excepting Nos. 10 and 11, were made upon sections of floors selected by the architect or engineer from

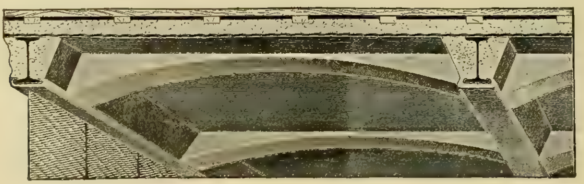


Fig. 7.

buildings under construction, and therefore give a fair and practical idea of the strength of expanded metal and concrete flat slab coverings for floors, roofs, etc.

Without giving more details than are shown by the tables for tests similar to No. 1, we will compare Nos. 10 and 11. In both these slabs the concrete came from the same "batch" or mixture, and both were allowed to set under like conditions; so without doubt the average crushing strength of each per square inch was the same. In No. 10 the slab was composed of concrete alone, and broke under a uniformly distributed load of 26 pounds per foot. In No. 11 the concrete slab of same thickness as No. 10 contained one sheet of 3-inch mesh, No. 10 gage, expanded metal imbedded in the lower or tension side of the beam, and broke under a uniformly distributed load of 256 pounds per square foot. This shows that the metal increased the strength of the concrete beam about ten times.

In Fig. 3 we have a cross-section of a concrete and expanded metal conduit built by the New York Expanded Metal Company as

an experimental section for the Jersey City Water Supply Company from design of Mr. R. Godfrey, civil engineer. The concrete below the springing of the arch was composed of one part Nazareth cement, two parts fine stone screenings and sharp sand and four parts of crushed stone; the portion above the spring line was composed of one part cement, two and one-half parts screenings and sand and five parts crushed stone. When the concrete was seven days old the centering was removed, and at the age of twenty-one days the concrete structure was tested. Fig. 5 is from a photograph of the loaded 12-foot section. Twenty-five tons of steel rails were placed upon three wooden saddles fitted on the crown of the arch 6 feet apart. Slight cracks were developed at points marked a, b, c in Fig. 3. About one ton of steel rails was afterward twice dropped 11 feet upon the loaded section, and the cracks were slightly widened, which, with a total deflection of $\frac{7}{16}$ inch, was the only change in the structure. The results from the above test

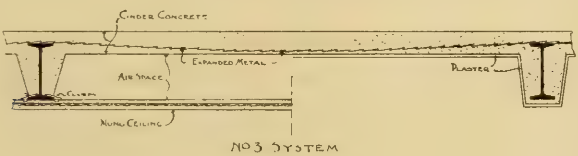


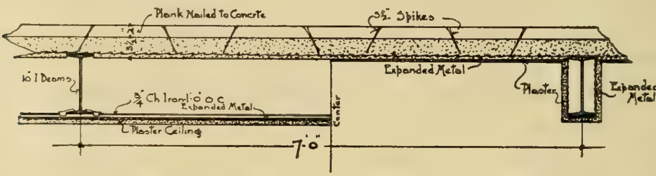
Fig. 8.

were so favorable that the writer has since built a similar conduit for the Massachusetts Chemical Company, at Walpole, Mass. A wheel pit 33 feet deep and 15 feet in diameter, with an 8-foot diameter inlet and an arched tail-race 15 feet in diameter, are now under construction for the same company. The walls of the wheel pit are 18 inches thick at the bottom, and reinforced with expanded metal. The flume deck, carrying a weight of 20 feet of water, and the floor of the generator house above are concrete and expanded metal flat slabs supported on I beams similar to our No. 3 system, shown in Fig. 8. The tail-race is to be built part of the distance in a trench 22 feet deep, with the following dimensions: Span 15 feet, rise 18 inches, concrete 6 inches thick at the crown and increasing to 8 inches thick at springing. One sheet of expanded metal, 3-inch mesh, No. 10 gage, is imbedded in the concrete to give the tensile strength where required.

Mill engineers are becoming interested in the possibilities of concrete and expanded metal construction, as it may be applied to their work. One of the large pulp mills in Maine has recently accepted our designs for concrete and expanded metal bleaching

chests. They are circular, about 14 feet in diameter and 20 feet high; the walls at the bottom 6 inches thick, with enough expanded metal imbedded in the concrete shell to give it the necessary strength when filled to the top with water.

Entire buildings are now made of cement and concrete on wooden or steel frames, and are practically fireproof. Many owners carry no insurance, and when insurance is carried the difference in rates warrants the extra expense of concrete construction over wood.



No. 4 System
With and Without Flat Ceiling

Fig. 10.

In Fig. 9 are sections of outside walls, partitions, etc., as built with expanded metal and Portland cement.

A reservoir has lately been covered over with a flat slab or blanket of concrete and expanded metal, and was supported only by piers about 12 feet on centers each way. This made a simple and easily constructed covering only 7 inches thick, which did not require such expensive centering as is necessary with the groined arches.

There is a growing demand for concrete structures, and I have tried to show by these few tests and remarks that expanded metal of the right shape and strength, properly used with concrete or plaster, will give a maximum strength with a minimum amount of material, and is applicable to many cases where concrete alone could not be used.

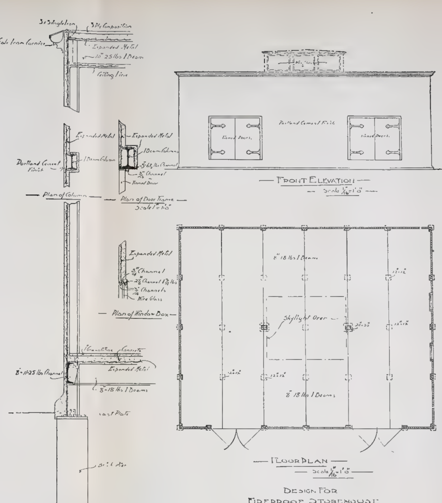

Front Elevation
Scale 1/16" = 1'0"
Floor Plan
Scale 1/16" = 1'0"
Design for
Fireproof Storehouse
By
Eastern Expanded Metal Co
And
Manhattan Concrete Co
42 Court St Boston
3/8" Scale
Plan of Column
Plan of Door Frame
Plan of Window Box
Expanded Metal
Portland Cement Finish
Tinned Doors
Skylight Over
Concrete Footings With Expanded Metal

Fig. 9

Description of Ransome System of Concrete Steel Floors.*

By M. C. Tuttle, of the Aberthaw Construction Company.

In order to properly understand the strength of the concrete steel arch, or, more correctly, beam, it is necessary to first consider the principle of the combination of the steel bar with the concrete. Square bars of steel are gripped by the ends, and are twisted cold until the angle made by the edge with the axis of the bar is about 20°. The bar thus becomes a long screw. The mortar of the concrete imbeds itself in the concave whorls of the bar, and, when set, in order to remove the bar an area of concrete must be sheared off equal to the superficial area of the cylinder inclosing the bar. In addition, some portion of every face presents a resistance to drawing through the concrete in a direction inclined to the axis of the bar. One component of this is a compressive resistance. Thus the bar is thoroughly and rigidly held throughout its entire length, so that it cannot stretch or draw, and can at no point bring upon the concrete a concentrated stress greater than it can bear.

Thus for practical purposes the bond of union is perfect, and the composite beam can be figured accurately by using the steel as a tensile member and the concrete as a compressive member. The common formula, which is sufficiently accurate for all practical work, is obtained by equating the external force $M = \frac{LS}{8}$ (giving the bending moment in the beam for a uniformly distributed load) against the internal force of the working stress of the bar into the arm between it and the center of gravity of the upper third of the concrete, which is the compressive portion of the beam considered. Equating these gives the formula $f = \frac{LS}{6\frac{2}{3} D}$. Wherein f is the fiber stress in the bar in pounds per square inch, L is the total load on the beam in pounds, S is the span in inches and D is the depth of beam from its top to the center of the bar. As cold twisting of mild steel increases the tensile strength and raises the elastic limit from 10 to 15 per cent., there is no appreciable error in increasing the denominator 5 per cent., changing $6\frac{2}{3}$ to 7, which makes a simple formula for actual use $f = \frac{LS}{7D}$. Numerous experiments show that there is greater strength in the actual construction than is indicated in the formula, which nominally gives a factor of from 4 to 5.

For short spans, say up to about 10 feet, we use a flat slab of concrete with the rods imbedded in the lower surface. It will be

*Manuscript received December 5, 1900.—Secretary, Ass'n of Eng. Socs.

seen that the tensile members of the slab run in straight lines, and this is an important advantage of our construction over those which employ a metal mesh, for where heavy loads or long spans necessitate an increase in the depth of the slab we can core out between the lines of stress, and thus, while retaining the depth and strength,

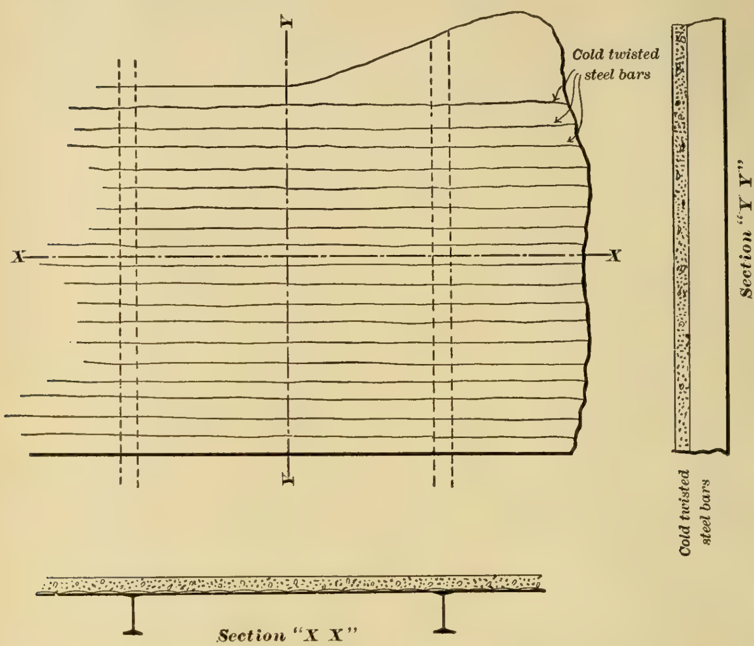


FIG. 1. DESIGN FOR FLAT SLAB FLOOR, RANSOME SYSTEM.

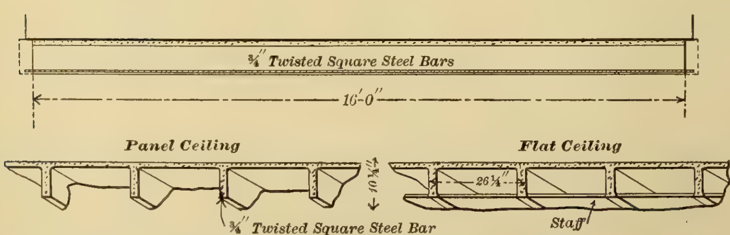


FIG. 2. DESIGN FOR FIRE-PROOF FLOORS, RANSOME SYSTEM.

can decrease the weight of the slab. This construction gives an absolutely fire-proof and rust-proof floor, which is capable of carrying large loads over long spans. It will be observed that the bar is thoroughly encased in the concrete, but nevertheless it is never more than 2 to 3 inches from the lower surface. Experiments by

Mr. E. L. Ransome, by those interested in the Monier and Melan systems and by Professor Bauschinger, of the Munich Technical High School, all prove that concrete affords a thoroughly trustworthy means of protecting steel against rust.

Fig. 1 shows the construction of a flat slab floor. Fig. 2 shows a section of floor where the concrete has been cored out between the bars which form the tensile members of this construction. Going

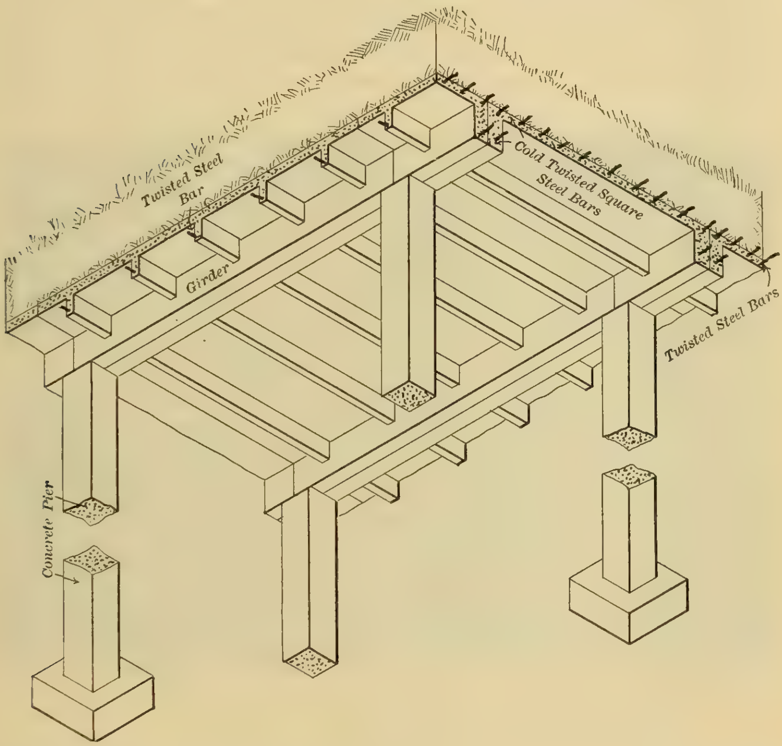


FIG. 3. DESIGN FOR ROOF OF SEPTIC TANK. ISOMETRIC VIEW OF TYPICAL BAY.

Safe Superimposed Load, including 2 ft. Earth Fill = 250 lbs. per sq. foot. Weight on each Pier with Full Load = 15 tons. Load on soil 3 tons per sq. foot. Girders, each half, 6″ x 15″ + 1¼″ bar. Beams 3″ x 10″ + ¾″ twisted steel bar. Slab 3″ thick with ¼″ twisted bars 10″ center to center. Piers 12″ x 12″ x 10′ long. Footings 2′ 3″ x 2′ 3″ x 12″ thick. Bays, 12′ x 8′ 6″ on centers.

one step further, we build floors with concrete girders. The concrete beams head into these girders. Fig. 3 is an isometric view of the roof of a septic tank designed on these lines.

Probably the best example of Ransome construction is the building of the Pacific Coast Borax Company, at Bayonne, N. J. In plan the building is about 75 feet by 200 feet, and is four stories

in height. The floors take their bearing on concrete columns 18 inches square and upon the walls. The floor bays are 12 x 24 feet. The floors were designed for carrying loads of 500 pounds per square foot, besides supporting jarring machinery; but they are often entirely covered with borax to a load of 1000 pounds per square foot.

As regards the strength of this construction: In the police court building at Chelsea, Mass., we built a flat slab $4\frac{1}{2}$ inches thick which had a clear span of 14 feet 8 inches between supports, reinforced by $\frac{3}{4}$-inch bars 6 inches apart between centers. It was designed for a live load of 100 pounds per square foot. Some ques-

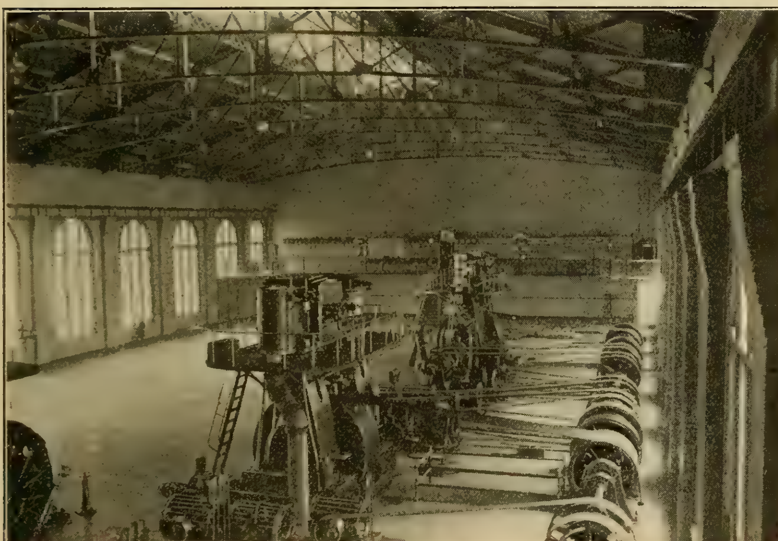
RANSOME FLOOR CONSTRUCTION, EDISON ILLUMINATING CO.'S POWER PLANT, PATERSON, N. J.

tion was raised as to its strength, and in order to reassure the doubters we put 40 barrels of cement three tiers high on the center of the span, giving a load equal to 200 pounds per square foot uniformly distributed. There was no apparent effect on the slab.

In 1897 the Building Department of the city of Boston made a test of a beam floor which spanned 15 feet. The beams were figured to carry 125 pounds per square foot, which equaled two tons each. The Building Department loaded one beam with six tons on the middle 13 feet. The deflection was 3-16 inch. This load remained on for three weeks, and the deflection disappeared when the load was removed.

At this building we constructed over an area a driveway with a span of 12 feet between supports. The thickness between the upper surface and the bottom of the concrete beams is about 12 inches. This driveway is subject to the usual jarring and pounding wear of a roadway. Heavy loads of flour are taken over it daily, and 4-horse loads of machinery have been hauled over it repeatedly. It is in as good shape to-day as the week it was built.

A specimen of our floor was tested by Professor Edward F. Miller, of the Massachusetts Institute of Technology. The concrete slab was 4 inches thick, 5 feet wide and 14 feet long, and was supported by 6-inch I beams spaced 4 feet 7 inches on centers.



RANSOME FLOOR, EDISON ILLUMINATING CO.'S POWER PLANT, PATERSON, N. J.

There was no side support. The specimen was 21 days old when tested. Imbedded at the bottom of the slab, and 6 inches apart on centers, were pieces of $\frac{3}{8}$-inch square twisted steel. The slab was designed for a load of 500 pounds per square foot. One end span of the slab was first tested by piling bricks on it until it was loaded with a uniformly distributed weight of 489 pounds per square foot. Under this load the center deflection between the I beams was 3-32 inch. The load was then increased to 724 pounds per square foot, and the deflection under this load was 5-32 inch. With the maximum load still remaining on the first span, the second span was tested by dropping a stick of spruce timber, weighing $164\frac{1}{2}$ pounds, from a height of 7 feet 10 inches so that it struck on

end in the center of the span. Five blows in all were struck in this way. Three of them were at an angle. The last two blows were fair, and both struck in the same space at about 20 inches from the I beam. No cracks were noticed after this. The third span was tested by setting a jack under an upright and turning it until a load of 7700 pounds was brought on an area $\frac{1}{4}$ x 9 inches. At this load a slight crack appeared, and the specimen gradually failed. The middle span was then loaded across the center through an I beam having a bearing surface $3\frac{1}{2}$ inches wide and 5 feet long. The maximum load put on at the center was 20,700 pounds, which equals

1900 pounds per square foot uniformly distributed, and the deflection at the time the first crack appeared at the bottom was 11-16 inch.

In our opinion, the most notable example of the strength of concrete steel floors is that of the Edison Electric Station at Paterson, N. J. Here the concrete floor has girders $9\frac{1}{3}$-foot span and beams $12\frac{1}{2}$-foot span, 18 inches in depth, united at the top by a panel 4 inches thick. The girders are supported by brick piers 20 inches square. A counter-shaft about 100 feet in length is bolted down to the panel of this floor; with 22 belts, two connected with 750 horse-power engines, the others driving dynamos, all pulling on one side. All the dynamos rest on the floor at any convenient point. Quite a number of compound engines of the vertical type are supported by two A frames bolted down to the floor, which in turn is supported

by long brick piers. The main shaft is about 18 feet in length, having a heavy fly wheel, and the armatures of two large dynamos wound on it, and supported by two pillow blocks which are bolted down to the 4-inch panel in the middle of the $12\frac{1}{2}$-foot span. These engines run very smoothly, and there is scarcely a perceptible tremor when standing in contact with the pillow block while the engines are running.

There are many other applications of this system, such as the construction of walls, chimneys, arch bridges, retaining walls, etc. We have confined our description only to the so-called flat arch floor.

Tests of Roebling Fireproof Floors.*

By Andrew W. Woodman, C. E.

In the many tests that have been made by the Roebling Construction Company on concrete floors as installed by them in modern, first-class buildings, the question that has always received the most careful consideration is the fire-resisting quality of the construction.

Incidental to these fire tests, however, there have been made a large number of load tests, which have demonstrated beyond a peradventure the fact that Roebling Standard Floor Construction will meet the requirements of the most exacting building laws.

As the subject of fireproofing is not the one under consideration, the records that will be here given relate only to the action of the arches tested under load.

The "Roebling Arch" consists of cinder concrete composed of 1 part high-grade Portland cement, 2½ parts coarse, sharp sand and 6 parts clean steam cinders, laid on a permanent stiffened wire center which is sprung between steel beams.

This wire center is made of a wire netting having round steel rods woven in at frequent intervals, the size of rod depending upon the span and rise of the arch. The wire is woven with 4 meshes to the inch in one direction and 2½ to the inch in the cross-direction. The stiffening rods are curved to the form of the arch, and are made of such length that at each end they project about 2 inches beyond the edge of the netting, so that when the concrete is laid there will be a good bearing of concrete on the lower flanges of the beams. After the center is sprung between the beams it is held in position by means of rods laid parallel to the axis of the arch and securely laced to the stiffening rods.

Fig. 1 shows such an arch with the cinder concrete filling in position and with a suspended wire lath ceiling attached to the lower flanges of the beams. This form of construction is well adapted for use in warehouses where provision must be made for heavy loads. In such cases a modified form of the arch, omitting the level ceiling and completely incasing the lower flange of the beam, is very extensively used. A section of this form of construction is represented by Fig. 2, and a photograph showing its appearance when finished is reproduced in Fig. 3.

The arch form of construction is somewhat more expensive than many of the lighter forms of fireproof floors, and, to meet

*Manuscript received November 24, 1900.—Secretary, Ass'n of Eng. Socs.

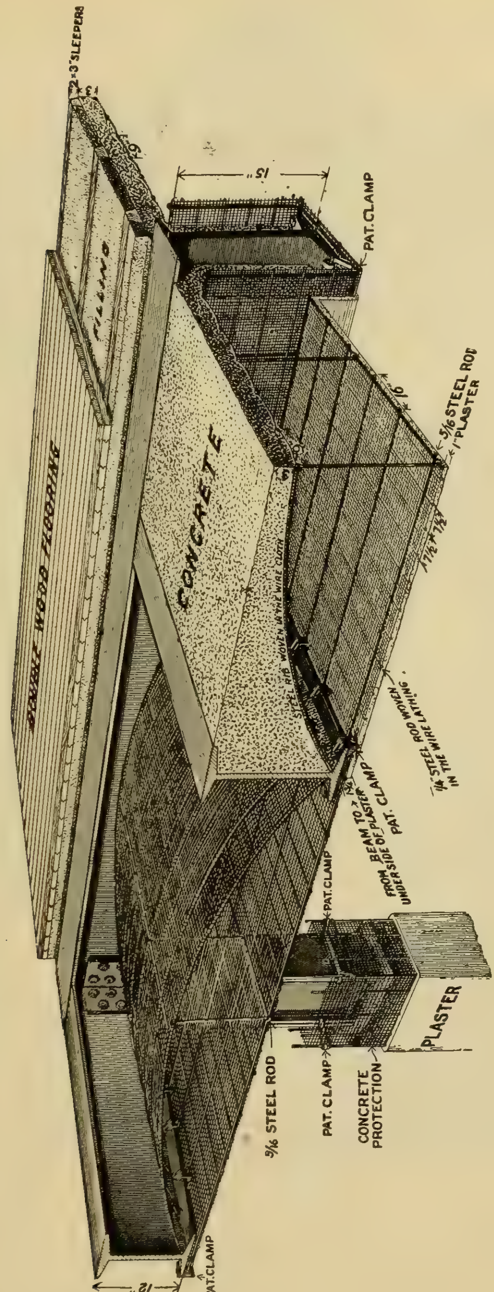

2"×3" SLEEPERS
15"
PAT. CLAMP
DOUBLE WOOD FLOORING
FILLING
CONCRETE
16"
5/16 STEEL ROD
1" PLASTER
STEEL RIB WOVEN IN THE WIRE CLOTH
1/4" STEEL ROD WOVEN IN THE WIRE LATHING
FROM BEAM TO UNDERSIDE OF PLASTER
PAT. CLAMP
PAT. CLAMP
PLASTER
5/16 STEEL ROD
PAT. CLAMP
CONCRETE PROTECTION
12"
PAT. CLAMP

FIG. 1.

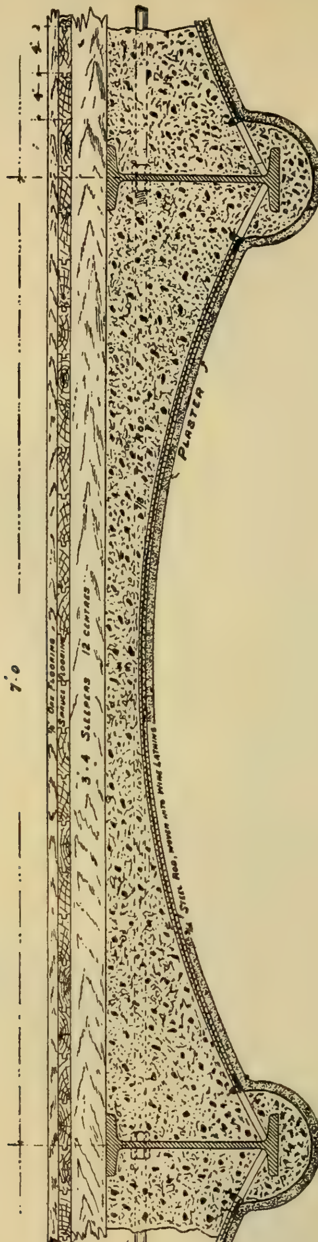


FIG. 2.

the competition of these cheaper floors, the Roeblings have developed a form of flat construction such as that represented by Fig. 4. This consists of a light steel framework imbedded in cinder concrete. The framework is built of steel bars placed on

edge, twisted at the ends and clamped tightly over the flanges of the supporting I beams, and braced or bridged throughout by means of steel spacers placed about 2 feet on centers. Underneath this light framework is placed either a permanent center of

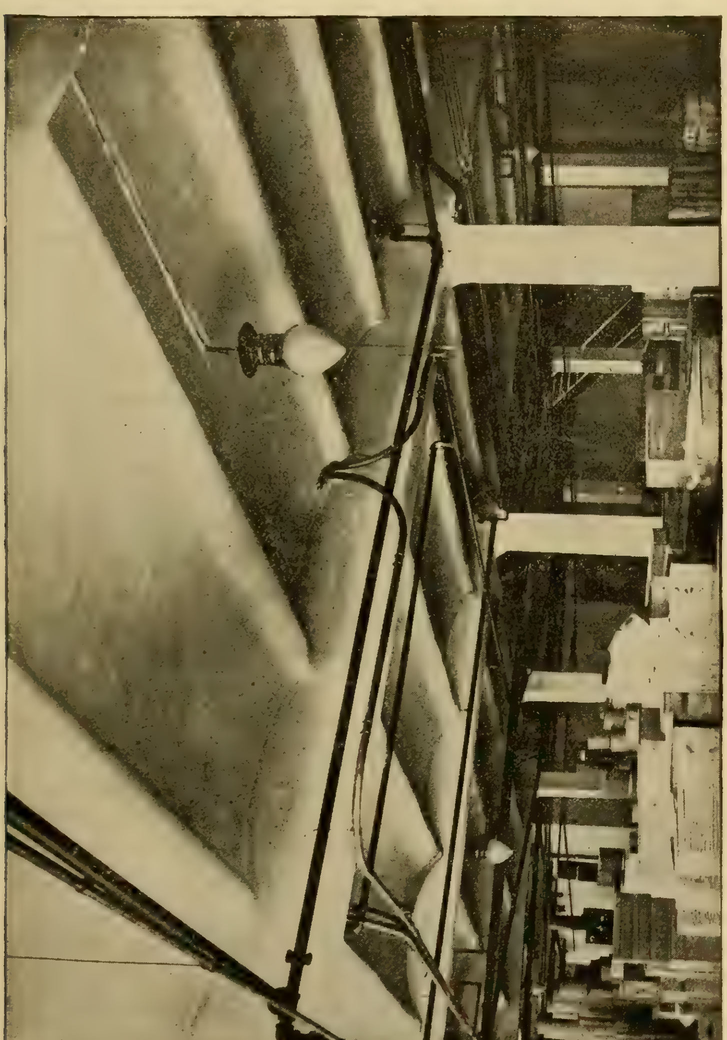


Fig. 3.

stiffened wire cloth or a temporary wood center, on which is laid the cinder concrete. Such floors are built with spans up to 16 feet, but the long spans are intended for only light, live loads.

With this brief description of forms and methods of construction, the reports of tests which follow will be more readily understood.

TESTS OF FLAT CONSTRUCTION.

Test I. An isolated section 4 feet wide, 8 feet between beams and $3\frac{1}{2}$ inches thick, with framing consisting of 2 x 3-16 inch bar, 16 inches on centers, was loaded at the center, the load being placed on a 12-inch plank across the slab. Under a load of 4000 pounds, which was equivalent to 250 pounds per square foot, the deflection was $\frac{1}{8}$ inch. Under 5200 pounds, which was equivalent to 325 pounds per square foot, the deflection was $\frac{5}{8}$ inch.

In this test the beams were not held rigidly in place, and the test was not carried to the destruction of the slab.

Test II. On a continuous floor where the span between beams was 9 feet $8\frac{1}{2}$ inches, a room 7 feet 8 inches from wall to plaster partition was loaded up to 106 pounds per square foot. The framing consisted of 2 x 3-16 inch bars, 16 inches on centers, so placed that the bottoms of the bars were about $3\frac{1}{2}$ inches below the top of the concrete. A brick wall had been built on the beam at outside of building, so that it was impossible to clamp the bars over this beam as is customary. There was a hole in the floor about 1 foot square, 1 foot from the plaster partition and close to the inside beam. Eight layers of furring tile, amounting to 106 pounds per square foot, were placed free of walls, partitions and girders, covering a space 7 x 8 feet.

Under this load the deflection was 3-64 inch. In the original design of this particular building 5-inch beams were specified, which, on 9 feet $8\frac{1}{2}$-inch span and under a 50-pound live load, would deflect about 5-16 inch, which is close to the limit on this span for the safety of the plastering.

Test III. At a building in Montreal where the spans were 15 feet $7\frac{1}{2}$ inches, a section 4 feet 5 inches wide was isolated by cutting with cold chisels. The slab was $8\frac{1}{2}$ inches thick and was framed with 2 x 3-16 inch bars placed 12 inches on centers. This was loaded with sand in wooden boxes, covering an area 15 feet 2 inches x 4 feet 2 inches. Loads and deflections were as follows:

With a load of 90 pounds per square foot the deflection was $\frac{1}{8}$ inch.

With a load of 120 pounds per square foot the deflection was 3-16 inch.

With a load of 180 pounds per square foot the deflection was $\frac{1}{4}$ inch.

It is interesting to note that under this load a 12-inch beam, designed in accordance with the Boston building laws, would deflect about 11-32 inch. The load was left standing one hour, then increased to 275 pounds and left standing over night. The

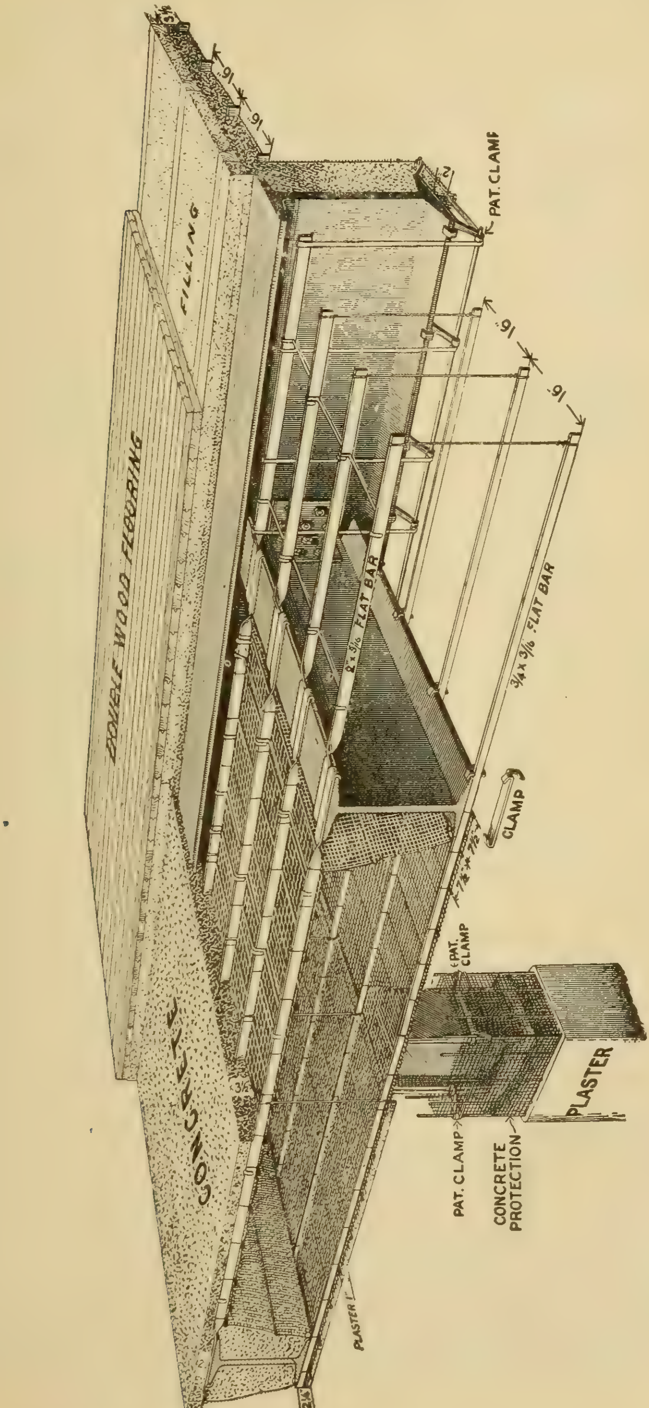

DOUBLE WOOD FLOORING
FILLING
CONCRETE
PAT. CLAMP
2 x 3/16 FLAT BAR
3/4 x 3/16 FLAT BAR
CLAMP
PAT. CLAMP
CONCRETE PROTECTION
PLASTER
PLASTER

FIG. 4.

total deflection was 7-16 inch. On removal of the load the floor immediately returned 3-16 inch, leaving thus a permanent deflection of $\frac{1}{4}$ inch.

Test IV. This same slab was subsequently tested with a sand load in a 4 x 5-foot box on the center of the span.

Amount of Sand in Box.	Deflection.
1′ 0″ high	Not appreciable.
2′ 0″ "	1/16″
3′ 0″ "	1/8″
4′ 0″ "	5/32″
5′ 2″ "	1/4″
5′ 8″ "	1/4″

This amounted to 10,170 pounds or the equivalent of about 300 pounds per square foot. The load was left standing twenty-four hours, after which time, as there was no further deflection, it was removed.

TESTS OF ARCH CONSTRUCTION.

Test V. A floor forming the top of a brick fire-test structure 11 x 15 feet inside was first fired, then drenched with water from a fire hose and then loaded. The arches were 10 inches deep, 3 inches thick at crown, on 10-inch I's, 3 feet 10$\frac{3}{4}$ inches on centers. The center one of three bays was loaded with 150 pounds per square foot and the structure was then fired. Temperatures ranging from 2000° F. to 2550° F. were recorded after the fire was well under way. After two hours the fire was quenched with a stream of water, and on a subsequent day the center arch was loaded to 186 pounds per square foot. Deflections under this load were not recorded.

Test VI. The form of construction as described in Test V, with 4-foot spans, was submitted to a five-hour test where the temperature reached 2300° F. as a maximum. The center arch was loaded with 150 pounds per square foot before the structure was fired. A fire stream from a 1$\frac{1}{8}$-inch nozzle, under 60 pounds pressure, was applied after five hours, at which time the temperature was 1950° F. Ceilings and walls were wet for fifteen minutes, then the top of the floor was flooded for seven minutes, after which time the fire on the grates was quenched. After the fire test the center bay was loaded with 600 pounds per square foot, with a resulting deflection of $\frac{1}{2}$ inch.

Test VII. A section of arch that was in the five-hour fire test previously recorded was subsequently loaded with a view to determining its ultimate strength. A portion of the arch 4 feet long was isolated by cutting through the concrete and the center space 2$\frac{1}{2}$ x 4 feet was loaded. The beams supporting the arch were shored up to prevent deflection. The deflection of the arch was measured under various loads.

Under 10,500 pounds it was 0.06 inch.

Under 19,900 pounds it was 0.2 inch.

Under 24,420 pounds it was 0.245 inch.

Loading was continued until the pile was about 12 feet high, weighed 40,550 pounds and was becoming unstable owing to the small area on which the load was supported. Three men then went on top of the pile to commence unloading. At this time, under a load of about 41,000 pounds, or 4100 pounds per square foot of loaded area, the deflection of the arch was $\frac{3}{4}$ inch. After the load had been removed it was found that the permanent deflection was $\frac{5}{8}$ inch.

Test VIII. A 5-foot Roebling arch on 10-inch beams, 12 feet long between brick walls, was loaded in the center with 10,000 pounds of pig iron placed on an area of 7 square feet and subjected to a fire test. Alongside this arch was a similarly loaded tile arch of 10-inch hard-burned terra cotta, made from material that had been delivered at a building in course of erection. At the expiration of four hours and five minutes the 10,000 pounds of pig iron fell through the tile arch and stopped the test.

Test IX. A 5-foot Roebling arch 14 feet long was built alongside a 5-foot arch of 8-inch semi-porous tile, and each arch was loaded with 150 pounds per square foot. The fire test lasted three hours and sixteen minutes, after which time the tile arch collapsed.

The deflections previous to failure of tile arch were 3.65 inch on the tile floor and 1.4 inch on the concrete floor.

Test X. Sections of arch 12 inches long were cut from the floor tested as described by Test IX, and loaded by means of a hydraulic cylinder on the center of arch. One section failed at 3000 pounds, and a second failed at 3200 pounds. A section of the same floor 46 inches long, and similarly loaded, broke under a center load of 11,900 pounds.

Records of other tests describing the action of Roebling arches under various conditions of loading might be given, but the limits of this paper will not permit. Such as are herein given relate only to strength, and omit much that from the standpoint of fireproofing would be of great interest; but it is hoped that these will suffice to demonstrate the suitability of Roebling floor construction for modern building work, so far as the question of strength is concerned.

The use of the Roebling arch in bridge floors has never received much attention, but from the report on the strength and cost of the brick and concrete arches described in the paper on "Tests of Brick and Concrete Arches," it would appear that the field might be entered with advantage.

A REVIEW OF CONCRETE-METAL CONSTRUCTION.

By Chas. M. Kurtz, Member Technical Society of the Pacific Coast.

[Read before the Society, March 1, 1901.*]

As indicated by the title, the nature of this paper is that of a review of progress along this line, as found in the various articles that have from time to time appeared in the engineering publications.

This paper might also be considered supplementary to the paper found in the transactions of this Society, written by our esteemed late president, Mr. G. W. Percy, which paper was read before this Society January 6, 1888, and entitled "Practical Applications of Iron and Concrete to Resist Transverse Strains."

In this paper Mr. Percy reviewed the applications of iron to concrete beams as invented by Thaddeus Hyatt and by E. L. Ransome. Stated briefly, Mr. Hyatt's method consisted in imbedding a skeleton of iron in the shape of a gridiron near the bottom of the concrete beam or slab, the principle of the construction being that the iron, used in the lower flanges of the beams, would serve only as the tie or tensile member, while the concrete formed the compression member and connecting web. His tests demonstrated that iron could be perfectly united with concrete so as to work in unison with it and form a compound beam or girder.

Mr. Ransome's method consisted in the substitution of square bars of iron or steel, twisted cold, instead of the iron frame of Mr. Hyatt's invention, to be imbedded near the bottom of concrete girders or flat slabs. This application of iron to concrete, though modified slightly in arching the beams transversely between the rods, has been used extensively and successfully in sidewalks and roofs.

Before describing the different systems, a few remarks will be made on the elasticity of concrete, the adhesion between concrete and iron, and the behavior of concrete as the preservative of iron.

Elasticity. As will be mentioned later, the elasticity of concrete has been practically demonstrated by the tests of the Austrian Society of Engineers and Architects,† and by numerous other tests; consequently, in combination of concrete and metal, both materials deform equally when subjected to a stress, and there-

*Manuscript received March 7, 1901.—Secretary, Ass'n of Eng. Socs.
†Oesterreichischer Ingenieur- und Architekten-Verein.

fore their stresses are as their relative moduli of elasticity. Mr. Thacher, in his formulas, puts the value of the modulus of elasticity of concrete at 1,400,000 pounds and that of steel at 28,000,000 pounds. The Austrian Society determined the value of the moduli of the elasticity of steel, concrete and mortar as follows:

For steel, 29,700,000 to 31,400,000 pounds.
For concrete, 1,400,000 to 4,000,000 pounds.
For 1.3 mortar, 5,000,000 to 6,000,000 pounds.

Expansion. M. Benniceau, a French author, gives the thermic expansion of Portland cement as 0.0000143 Celsius, while iron has 0.0000145.

Adhesion. It has been well demonstrated that there is a strong adhesion between concrete and iron. This great adhesion is attributed to a chemical connection between the silicates of cement and steel. Professor Bauschinger found the adhesion between mortar and iron to be between 570 and 640 pounds per square inch.

To determine values of the adhesion between iron and cement mortar, Mr. W. A. Hoyt, a student at the University of Wisconsin, last year conducted a series of experiments to determine the stress per square inch of metal surface required to pull imbedded bolts from the mortar. He experimented with polished bolts, rusty bolts, bolts with normal surface and bolts that had been coated with a neat cement mortar before being imbedded in the concrete. While his experiments were not entirely satisfactory, on account of a lack of uniformity in the sand used (which, however, is something liable to happen in practice), the average results of his tests are as follows:

Age of concrete, ten weeks.
Adhesion of polished bolts, 440 pounds per square inch.
Adhesion of rusty bolts, 520 pounds per square inch.
Adhesion of bolts with normal surface, 570 pounds per square inch.
Adhesion of bolts coated with neat cement, 820 pounds per square inch.
Adhesion (average), 588 pounds per square inch.

Concrete as a Preservative of Iron. It has been well proven that cement acts as a preservative of iron and steel, and many instances could be cited showing that iron or steel will not rust when imbedded in concrete, even if the concrete itself be immersed.

The common principle of all concrete-metal construction is that the imbedded metal supplies the quality of tension, a quality which is lacking in the concrete itself, and in return the concrete stiffens the metal.

Other systems besides the Ransome system of concrete-metal construction, which are specially favored in practice to-day, are the Monier, the Wünsch, the Melan, the Thacher, the Hennebique and the "expanded metal" systems. Each of these systems is individually a proper subject for a paper, so the discussion of the several systems will be made as brief as is consistent with a review of this kind.

The most important and popular practice in concrete-metal construction to-day is the reinforcing of the arch ring of a concrete arch by the imbedding of iron or steel in various forms. An arch fails usually by tearing apart near the center at the intrados, and at the haunches at the extrados, the material, at these places in the arch, being unable to withstand the tension to which they are subjected when too heavily loaded.

The most frequent employment of the Melan, Wünsch and Thacher systems is found in the concrete-metal arch. The Monier is the most flexible system, and consequently possesses the greatest

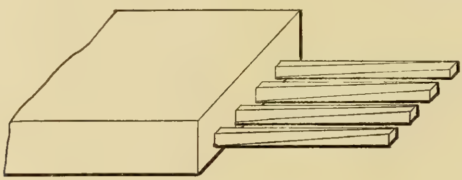


FIG. 1. RANSOME.

variety of applications. The Melan, Wünsch and Hennebique systems are extensively used for floors in Europe, while American practice seems to favor the Monier and modifications of the Monier system and the expanded metal system.

THE RANSOME SYSTEM.

It is a matter of special interest that the first concrete-steel arch built in the United States was constructed on the Ransome system. This arch is in Golden Gate Park, San Francisco, Cal., and was erected in 1889. A second or similar design was erected in 1891. In this system the twisted steel bars are imbedded in the concrete arch ring in pairs, about one foot C. to C., one bar of each pair being near and parallel to the intrados and the other near and parallel to the extrados. The merits of this system are so generally known and recognized, and no doubt, especially so by members of this Society, that further comment on it seems unnecessary.

THE MONIER SYSTEM.

The Monier system, until within the last two years, was practically unknown in this country, but since 1880 it has been applied in a great variety of constructions in Europe. Among these applications may be mentioned gas and water reservoirs, grain elevators, sewer pipe, flumes and culverts, fireproof floors and arch bridges.

In this system the metal consists of a netting of two series of parallel steel or iron rods, $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter, which intersect at right angles and are generally spaced from two to four inches. At the intersections the rods are bound together with wire $\frac{3}{64}$ to $\frac{1}{8}$ inch in diameter. In arches of this system a netting is imbedded near the intrados and sometimes a second one near the extrados. In the tanks, pipes, etc., the netting is imbedded near the center of the shell.

No attempt to construct an arch of a long span in this system was made until it had been well tested as to its merits by the Austrian Society, and then one of striking dimensions was built at Wildegg, Switzerland, in the autumn of 1890. It crosses an industrial canal at an angle of 45°, and has a total span of 122.1 feet, with a rise of only 11.5 feet, less than a tenth of the span. The bridge is 12.8 feet broad. The Monier arch proper is 7.9 inches thick at the center, and 25.6 inches at the abutments. The spandrel walls were likewise constructed on the Monier principle and are connected at each end by two ties. The abutments are of concrete, and a backing of this material is run up on the arch for some distance, as shown in the cuts. The bridge was required to support a uniform load of 84 pounds per square foot, but on completion it was put to the test for the maximum load it would ever carry as a highway bridge. The tests were very satisfactory. For further description of this bridge see *Engineering News* for May 23, 1891.

As pointed out by Mr. Edwin Thacher, member of the American Society of Civil Engineers, in his paper on concrete-steel bridge construction in *Engineering News,* September 21, 1899, this system has some practical disadvantages. Quoting from this paper: "The wire nets are so flexible and unruly that it has been found impracticable to imbed them in concrete containing coarse aggregates like gravel and broken stone, consequently all the strictly Monier arches that have been built up to this time have been built with 1 to 3 mortar, which, as compared with 1 : 2-$\frac{1}{2}$: 5 concrete, is weaker and costs considerably more."

The theoretical discussion of a Monier arch or any other concrete-metal arch is a difficult task, on account of the different materials combined, and it is not the purpose of this paper to take up the subject in that manner. Discussions may be found in the "Minutes of the Proceedings of the Institution of Civil Engineers," Vol. CXXXIII, page 376, and in the "Zeitschrift des Oesterreichischen Ingenieur- und Architekten-Vereines," for September 23, 1898.

An excellent descriptive article by Mr. E. L. Heidenreich on Monier construction is found in the *Journal of the Western Society of Engineers* for June, 1900. Mr. Heidenreich enumerates some of the wonderfully diversified applications of the construction,

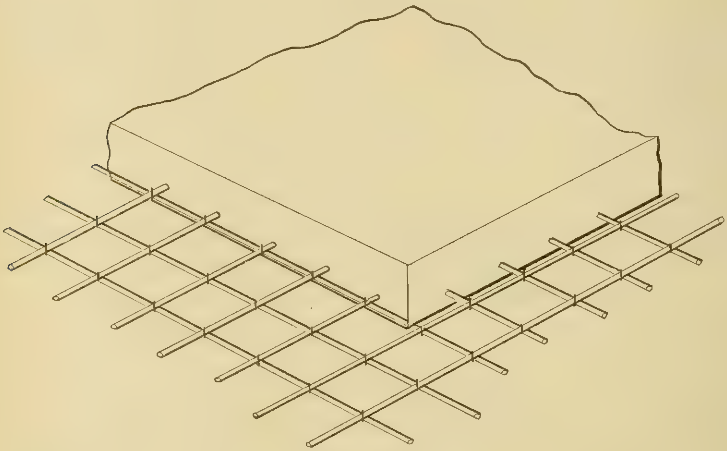


FIG. 2. MONIER.

among which are reservoirs for storage of water, wine, oil, pulp, grain, cement, etc., bridges and preservation of steel in bridges and viaducts, buildings, floors and partitions, culverts and flumes, fortifications, etc.

One of the most recent applications of the Monier construction is the use of specially constructed pipes for pile covering, to protects the pile against the attacks of the teredo navalis, or cobra. This method of protecting piles was used in constructing five timber piers for a traffic bridge near Sydney, New South Wales (each pier consisting of a bent of three piles), and is described by Mr. E. M. De Burgh, member of the Institution of Civil Engineers, in a paper in the "Proceedings of the Institution of Civil Engineers." An extract of the paper appears in *Engineering News*, February 7, 1901. Briefly described, the method was this:

After a pile, having been previously coated with Stockholm tar, had been driven, sufficient length of the pipe to reach from below the silt and into the clay, to above high water, was slipped over the top of the pile and sunk to a proper depth by means of a water jet being worked around the bottom, and pressure being applied at the top by means of screw-jacks. Mr. De Burgh is satisfied that it will prove of great durability and outlast the pile, which, being iron-bark, may be counted on for a life of thirty years when protected from the teredo. The cost is estimated between 50 and 100 per cent. greater than that of coppering. The same paper also gives an account and description of Monier cylinders being used for foundations as a substitute for the cast iron cylinders used largely in New South Wales. That concrete-metal in sea water is a complete success is questionable. Experiments on the action of sea water upon concrete-steel show that electrolytic actions take place which cause deterioration of the steel or iron. See Ann des Ponts et Chausseés, Fourth Quarter, 1899.

THE WÜNSCH SYSTEM.

The concrete-metal arch known as the Wünsch system was invented by Robert Wünsch, of Hungary, in 1884. In this system, arch ribs of metal, consisting of an arched lower and horizontal upper member, both of which are run together and riveted at the crown, are imbedded in the concrete. The two members of the rib are connected at the piers and abutments by vertical and transverse lower members deeply imbedded in the concrete.

In Fig. 4 is shown an excellent example of this construction. It is the plan of a Wünsch arch of 83 feet span,—the longest, up to date, of this system,—constructed in 1897 over the Miljacka River at Sarajevo. The chords of the metal ribs are made up of two angles, and the vertical and transverse members of channels.

When a Wünsch bridge is made up of several spans, as is the case with the one constructed near Neuhausel, Hungary, the horizontal or upper chords of the metal ribs are made continuous from one arch to another. This bridge had six arches, of the following dimensions: Span, 55.8 feet; rise, 3.7 feet; thickness at the crown, 9.8 inches; at the springing line, 54.3 inches. The chords of the ribs were made up of two 3-inch angles spaced 20 inches C. to C. The entire ironwork weighed 88,180 pounds and the amount of concrete was 1346 cubic yards. The total cost was only $13,700.

In building the arches, after the centering was in position, the iron members were put in place and the concreting began.

The concrete was made of one part Portland cement and six parts of sand and gravel for a layer of 10 to 12 inches thick. The arch concrete was carefully rammed in layers at right angles to radial lines, and especial care was taken in ramming the concrete that came below the arched bottom chords. The centering was left undisturbed for thirty days after the last arch had been finished, and the striking of the centers was commenced at the two center arches. The bridge was tested by the application of a uniform load of 82 pounds per square foot and also by a very heavy live load, the maximum deflection being 0.138 inches and the set 0.031 inches. For further descriptions see *Engineering News*, November 16, 1893.

The Wünsch system of concrete-metal arches does not seem to be an economical design. There is no arch ring proper, but the entire arch, from the under surface to the pavement of the roadway, is a massive monolithic mass of concrete. There are no bridges of this type in the United States.

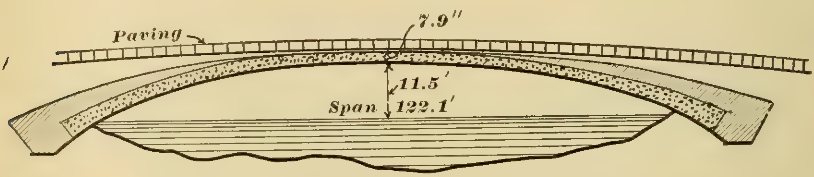


Fig. 3. Monier Arch at Wildegg, Switzerland.

THE MELAN SYSTEM.

This style of concrete-steel construction was invented by Joseph Melan, of Austria, in 1892, and was patented in the United States the following year. It consists of curved I beams or lattice girders imbedded vertically in the concrete of the arch ring and abutments. These ribs are sometimes connected transversely at their ends in the abutments by cross angles, and are sometimes provided with individual anchor plates. If the bridge consists of several arches, the ribs in each arch are, in some cases, independent of those in adjacent arches, being connected only by the concrete, but in the large bridge recently built at Topeka, Kan., the ribs were riveted to a common plate at the piers.

The merits of this system were quickly recognized in this country as well as in Europe. The result of such recognition has been the erection of bridges of the Melan type in parks where a handsome and esthetic design was desired, and the displacing of iron and steel truss bridges where *permanence* was the quality desired.

Among the more important of the park bridges of the Melan system constructed up to date is the Melan arch at Eden Park, Cincinnati, designed and built by Fr. Von Emperger, C.E., in 1895. This arch has a span of 70 feet and a rise of 10 feet, and carries an 18-foot roadway and two concrete sidewalks of 5 feet each. The concrete (in the proportion 1 : 2 : 4) is 15 inches thick at the crown and 48 inches at the haunches. The I beams are 9 inches deep, weighing 21 pounds per foot, spaced 36 inches apart, and are supported by a cross-channel at each end. As this arch is an excellent example of the Melan type, its construction will be briefly described.

After the excavation had been made and the false work erected, the bent ribs were laid, splices and cross-angles fastened and the concrete in the abutments started so as to inclose the ends of the ribs. Then wing walls and pillars were built to train the workmen, who were common laborers, paid at the rate of $13\frac{1}{2}$ cents an hour.

The arch was built in two longitudinal halves, each of them started on both sides and closed up to the center in one day of twelve working hours.

On completion of the arch proper and the removal of the boards on the face walls, the filling of the bridge was put in and completed to the level of the coping stone, where the work was stopped for the winter. In the spring the false work was struck and the work completed.

After the removal of the false work the filling was compressed with a 15-ton roller, a very trying test, as the filling at the crown was not more than 6 inches thick over the concrete. See *Engineering News,* October 3, 1895. Other examples of this style of bridge constructed in parks are:

The two-arch bridge at Hyde Park, N. Y., on the estate of F. W. Vanderbilt, designed by the Melan Arch Construction Company and built by W. T. Hiscox & Co., both of New York. For description see *Engineering Record* of January 14, 1899.

The Franklin bridge in Forest Park, St. Louis, Mo., which has a span of 60 feet and a rise of 15 feet $6\frac{3}{16}$ inches. The ring is 11 inches thick at the crown, increasing to 30 inches at the springing line, and has imbedded therein eleven 8-inch, 18-pound steel I beams, spliced at the crown and spaced 3 feet C. to C. See *Engineering Record*, December 10, 1898.

The Melan arch at Stockbridge, Mass., designed and constructed by Fr. Von. Emperger, C.E. This is a 7-foot footbridge of 100 feet span and 10 feet rise. The ring is 9 inches

thick at the crown and 30 inches at the haunches, and has imbedded four 7-inch I beams spaced 28 inches apart and raised 2 inches from the soffit. See *Engineering News*, November 7, 1895.

As examples of the Melan arch built by cities for carrying streets across rivers may be mentioned the concrete-steel arch bridge at Topeka, Kan., across the Kansas River; the bridge at Paterson, N. J., carrying West street across the Passaic River; and two concrete-steel bridges in Indianapolis across Fall Creek at Illinois street and Meridian street.

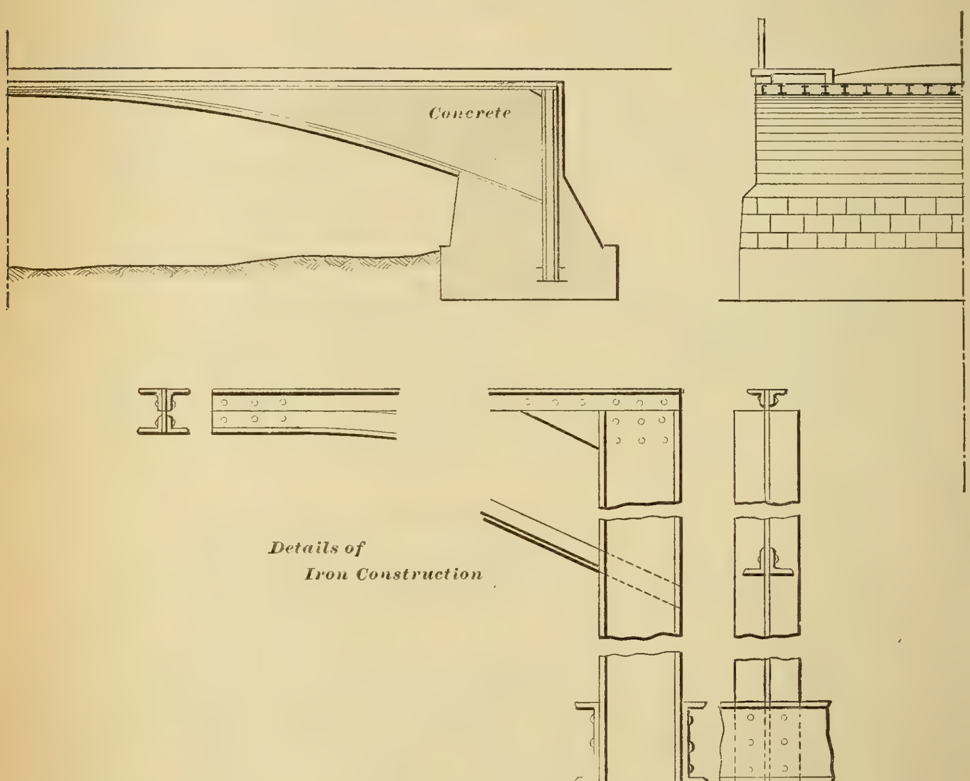


FIG. 4. WÜNSCH ARCH.

The Topeka bridge is the largest concrete-metal bridge ever built in the country. It was designed by Keepers & Thacher, civil engineers, and consists of five spans,—one 125 feet, two 110 feet and two 97½ feet,—and carries a roadway 26 feet wide and two 7-foot sidewalks. It replaces an old six-span, iron truss structure of considerably greater length. In each span twelve lattice girders placed 3 feet C. to C. are imbedded in the concrete,

by which they are completely surrounded. See *Engineering News*, April, 2, 1896, for further description.

The West street bridge at Paterson, N. J., consists of three arches of 88.25 to 89 feet clear span, each arch having a rise of 9.5 feet. The concrete of the arch rings is 15 inches in thickness at the crown, gradually increasing to 66 inches at the skew backs and imbedding 10-inch I beams weighing 25 pounds per foot, spaced 3 feet C. to C. The bridge was designed by the Melan Arch Construction Company and Mr. Edwin Thacher, member of the American Society of Civil Engineers, and is an example of the adaptability of the concrete-steel arch to locations where the voussoir stone arch is not practical. The latter would hardly have been designed with a rise less than one-sixth the span, with the foundation available at this place, whereas the bridge built has a rise of only 1-9.4 of the span. A voussoir arch at the location would have given either objectionable grades on the approaches, perhaps with considerable property damages, or would have obstructed the river channel with several more piers, to an extent prohibitory. See *Engineering News*, March 16, 1899.

In Indianapolis the Board of Public Works, after considering the replacing of many of the old iron and steel bridges by new structures of a more permanent character, deemed it desirable to construct stone bridges across Fall Creek at Illinois street and Meridian street It was first contemplated to have these bridges built entirely of natural stone, but in order to insure a greater waterway without greatly increasing the width of the stream it was found to be more economical to construct these bridges on the Melan system.

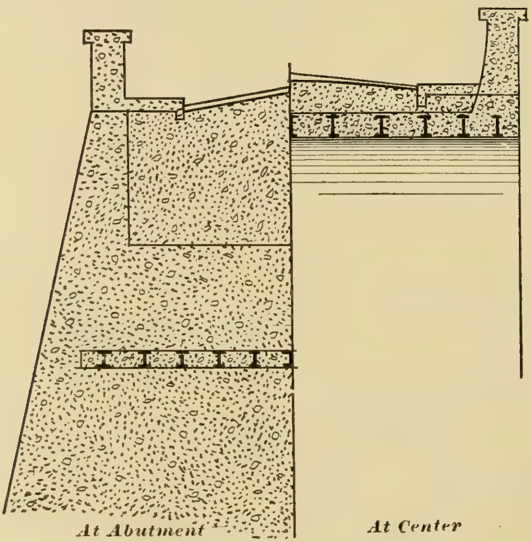
Both of these bridges are skew bridges, the lines of the piers and abutments making an angle of 70° with the street line. Each bridge is composed of three arches of 74 feet span, the piers being 8 feet wide and the abutments 20 feet. The thickness of the arch rings at the crown is 16 inches and at the piers 60 inches. Ten-inch I beams, 25 pounds per foot, spaced 3 feet C. to C., are imbedded in the concrete of the arches. The beams are bent at the mills to conform to the plan of the arch and were shipped in two sections. After they had been placed in position on the centering they were spliced at the center by means of top and side plates and thoroughly riveted. See *Municipal Engineering* for February, 1901.

A complete list of the Melan bridges built in the United States up to the year 1899 may be found in the *Polytechnic* for March, 1899.

THE THACHER SYSTEM.

This system can best be described by quoting from the article entitled "Concrete-Steel Bridge Coustruction," written by Mr. Edwin Thacher, member of the American Society of Civil Engineers, in the *Engineering News*, September 21, 1899.

"Steel bars in pairs, spaced at proper distances apart and spliced at convenient intervals, are imbedded in the concrete near the outer and inner surfaces of the arch, and extend well into the abutments or piers. The bars of each pair have no connection with each other, except through the concrete, but each bar is provided with projections, preferably rivet heads of extra height,



Transverse Section

Fig. 5. Melan Arch.

but which may be lugs, dowels or bolts, spaced at short intervals, thereby providing a mechanical reinforcement of the adhesion between the steel and the concrete, so that a complete crushing or shearing of the concrete must take place before a separation can be effected. The bars act as the flanges of a beam to assist the concrete in resisting the thrusts and bending moments to which the arch is subjected. The shearing stresses are small, and the concrete is amply able to take them many times over." Continuing, Mr. Thacher says: "The principal advantages which this system offers over those previously mentioned may be stated as follows: It gives a larger moment of inertia, and consequently

greater strength for the same amount of steel. In the Melan system I beams are usually used, which, if buried in the concrete, are necessarily less in depth throughout than the depth at the crown, and as the greatest bending moments are always at or near the spring, the use of I beams gives the less strength and reserve of strength where the greatest is needed. If the beam is made of angles with lattice connections, as at Topeka, it is not practicable even then to follow out the lines of greatest strength, as the beams become too deep and unwieldy. A more reliable connection is secured between the steel and concrete than in any system that depends on adhesion alone." Mr. Thacher was granted a patent on his design January 10, 1899.

Mr. Thacher's paper also enters into some of the details of calculations of the Thacher and Melan systems, which I will not repeat here.

The most important bridges of this system constructed up to date are the new arch bridges at Niagara Falls, connecting the mainland with Green Island and the latter with Goat Island. The bridge between the mainland and Green Island consists of three spans, the two end spans being each 103½ feet long, with 10 feet rise, while the center span has a length of 110 feet and a rise of 11½ feet. The arch ring in the end spans is 38 inches thick at the crown and 70 inches at the springing line, and in the center span 40 inches at the crown and 76 inches at the springing line. Imbedded in the concrete, spaced 3 feet C. to C. and 3 inches from the intrados and extrados are pairs of flat steel bars, connected vertically by bolts at intervals of about 32 inches. The concrete in the arches between skew backs is composed of one part Portland cement, two parts sand and four parts broken stone or gravel, which passed through a 1¼-inch ring, including the total product of the crusher between 1¼ inches and ¼ inch. For the foundation abutments, piers and span-drills the concrete is made in the proportion 1 : 3 : 6. Limestone facing covers the entire structure, including the piers and abutments below water, only excepting the soffit of the arches between the ring stones on each face and that portion of the abutments buried in the banks. In building, the concrete for the arches was started simultaneously from both ends of the arch and laid in longitudinal sections so as to inclose at least two ribs.

This bridge is of great architectural beauty, and adds much to the appearance of the state reservation at this point. For further description see *Engineering News*, December 6, 1900, and *Engineering Record*, February 16, 1901.

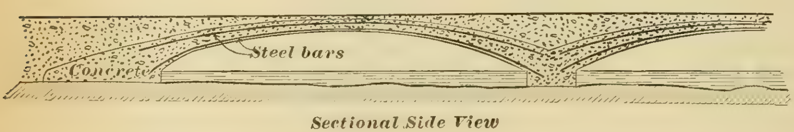
Other bridges built on this system are listed by Mr. Thacher in his aforementioned article in *Engineering News*.

THE HENNEBIQUE SYSTEM.

But little information is to be found respecting this system in English or American publications, as its employment in practice has been confined almost entirely to France, and the writer has not had access to the French publication entitled "Revue Technique."

In the discussion on Monier construction in the *Journal of the Western Society of Engineers*, June, 1900, the Hennebique system is described by Mr. Ralph Modjeski, member of the Western Society of Civil Engineers, as follows:

"The Hennebique system, which is used very extensively in France, has its principal application in floors of buildings, partitions, etc. The rods used here are much heavier than in the Monier system. Two or more of the rods are placed lengthwise near the bottom of the concrete beam, and are tied to the upper portion of the beam and to the floor slabs by thin vertical bars."



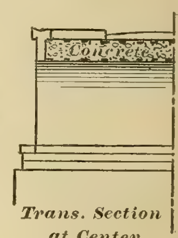


FIG. 6. THACHER ARCH.

"Computations for Ribbed Beams of Iron and Concrete on the Hennebique System," a mathematical treatment of the proportions for concrete girders with imbedded iron rods, is found in the "Zeitschreift des Oesterreichischen Ingenieur- und Architekten-Vereines," September 15, 1899.

THE EXPANDED METAL SYSTEM.

Expanded metal has also been successfully applied to concrete in a manner somewhat similar to the application of the netting of rods in the Monier system, both in floors and arch bridges, but principally in floors.

The use of expanded metal in constructing fireproof floors, partitions, etc., is too familiar to require description. Many tests of slabs of concrete-expanded metal have been made in the last

three years. The best literature on these tests and the records of the tests themselves are found in the paper on "Steel Concrete Construction," by Mr. George Hill, associate member of the American Society of Civil Engineers, and in the correspondence and discussion of the same, in the "Transactions of the American Society of Civil Engineers, June, 1898." The results, tables and formulas in the paper and discussions were not entirely satisfactory, and will not be repeated here.

An arch of 21-foot span and 6-foot 8-inch rise, built at Oconomowoc, Wis., for P. D. Armour, Jr., designed by Mr. C. F. Hall, C.E., has imbedded in the concrete arch ring flat rods and a sheet of expanded metal of No. 16 gage, 2½-inch mesh. See *Engineering News*, October 19, 1899.

OTHER SYSTEMS.

A floor system that has been well tested experimentally by fire and excessive loads is the Roebling system. This system consists essentially of an arch of woven wire netting springing from the lower flanges of the floor beams and covered with a bed of concrete, which is leveled up with the upper flanges of the beams. The netting is strengthened by iron rods at intervals of about nine inches each way, the wires being woven around the rods so as to form one sheet of netting. See *Engineering News*, July 18, 1895. The fire tests are described in *Engineering News*, December 2, 1897.

There are other systems besides those above described, but as they are not important and are not extensively employed in practice, descriptions of them will be omitted.

THE AUSTRIAN SOCIETY TESTS.

This paper would be incomplete without some mention of the tests of brick, concrete, Monier and Melan arches made by the Austrian Society of Engineers. Tests to destruction were made for spans of 4.43, 8.86, 13.3, 52.8 and 74.5 feet. A synopsis of these tests is found in an article by Mr. Mansfield Merriman, member of the American Society of Civil Engineers, in the *Engineering News*, April 9, 1896. A more complete report appears in *Engineering* (London), February 21, 1896. These tests demonstrated that the theory of elasticity gives the only solid foundation for theoretic investigations, since the deformations were practically proportional to the stress in all cases where the elastic limits were not exceeded.

MISCELLANEOUS APPLICATIONS.

A factory building. A large monolithic factory building for the Pacific Coast Borax Company at Constable Hook, Bayonne, N. J., was designed and constructed by Mr. E. L. Ransome in 1898. The structure is built entirely of concrete reinforced by steel rods. The design embraced the construction of solid concrete floors, supported on reinforced concrete beams and joists and carried by hollow concrete walls and solid concrete columns and beam-piers in the hollow concrete walls. The Ransome system is employed throughout. See *Engineering Record*, July 30 and August 20, 1898.

Retaining walls. Concrete retaining walls reinforced by imbedded steel of different forms have been designed and built. One employing the Hennebique system was constructed at the

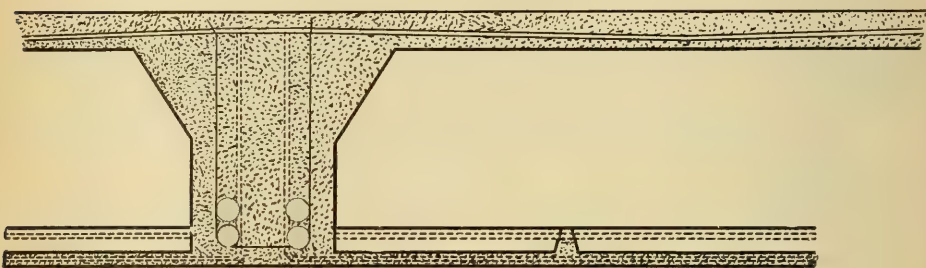


FIG. 7. HENNEBIQUE.

Paris Exposition of 1900. See *Engineering News*, February 15, 1900.

In making excavations for tall office buildings, retaining walls have been constructed of concrete reinforced by horizontal trusses of heavy lattice girders serving to give the wall strength against flexure and transmit the pressure to the ends of the longitudinal walls upon which they abutted. See *Engineering Record*, June 18, 1898.

A concrete-steel retaining wall was built in Columbus, Ohio, in 1900, by Mr. F. A. Bone, engineer of the Oregonia Bridge Company, Oregonia, Ohio. His construction employs the principle on which a tree depends for its stability. "The tensile strains at the back of the wall are transmitted by the metal to the concrete base, which is loaded by the earth and thus held down like the roots of a tree." See *Engineering Record*, November 10, 1900.

Roof of covered reservoirs. A new 25,000,000-gallon covered reservoir now under construction for the Louisville Water Com-

pany has a roof made up of groined concrete-metal arches, the reinforcement consisting of the steel bars of the Thacher system. The arches are supported by the division walls and concrete pillars. The spans are approximately 19 feet with a rise of 3.8 feet, and the concrete is 6 inches thick at the crown and 36 inches at the springing line in radial lines, and are constructed of Portland cement 1 : 2 : 4 concrete.' See *Engineering News*, January 10, 1901.

Concrete-steel ties. Steel and concrete ties have been tried experimentally by the Pennsylvania Railroad in Chicago in one of the main tracks. They were in the track ten months and were then removed because of the failure of the device locking the rail to the tie, although 10 out of the total 30 had cracked at the end of seven months. The tie was patented by Mr. C. C. Harrel, of Chicago, but afterward modified by Mr. J. J. Harrell, of Wilmington, Del. As described in the *Engineering News* of January 10, 1901, it is as follows: "The design is a combination of two channel bars, seven feet long, forming the top and bottom of the tie, separated by distance pieces, and braced under the rail seats by vertical and inclined struts between the bars. A short piece of channel iron forms the rail seat, and through this pass the anchor bolts, the heads of which are under the lower channel bar. The whole structure is imbedded in concrete, with the exception of the rail seat. The rail rests on a shim or packing plate and is secured by bolted clamps, filling the rail base and the edge of the channel. The complete tie is 7 feet 8 inches long, 8 inches thick, 5 inches wide at the top and 8 inches at the bottom, the weight being about 300 pounds."

The cost of the ties used was about $8 each, but it is believed that the cost will be less than $1 each, if made in any quantity.

COMPARATIVE COST OF CONCRETE-STEEL BRIDGES.

In bidding on a bridge for Junction Hollow, Shenley Park, Pittsburg, Pa., Keepers & Thacher bid on a Melan arch having a clear span of 300 feet with a rise of 66 feet 2 inches, flanked by 70-foot and 61-foot spans, and having a width of 80 feet between parapets. This bridge was 590 feet long and covered 47,200 square feet in clear between stone parapets, erected and paved complete, ready for traffic, and their bid was about $7 per square foot, only a trifle more than was paid for the steel arch which was accepted and built.

In St. Louis the Council, having appropriated $5500 for constructing an arch bridge in Forest Park, Mr. John Dean, the

Engineer of the Park Department, prepared a plan for a concrete arch bridge of 60 feet span. Fearing that the appropriation was insufficient to provide for the structure as designed, the design was sent to the Melan Arch Construction Company, of New York. This company applied its system to Mr. Dean's design, inserting steel I beams in the ring and reducing the thickness of the concrete. The contract was then awarded for the work complete, exclusive of the roadway and sidewalk pavements, at a price several hundred dollars less than the appropriation.

A very important feature of the cost of concrete-steel bridges is that their first cost is their only cost,—a great advantage over the steel bridges, which invariably require a constant outlay of money for maintenance and depreciation.

In conclusion, while I realize that this paper has nothing new to offer to the engineering public by collecting and putting together the above data and information, it has been my aim to make something that will be of utility to any one desiring a general knowledge of concrete-metal construction. Considering the great progress in concrete-metal construction and its present popularity, its future seems very promising. Mr. George S. Morison, member of the American Society of Civil Engineers, is quoted as saying: "I fully believe that we are now only at the beginning of concrete construction, and that, if the results which we hope for can be attained, with concrete structures with metal structures inside, the time will come when this will be the one method of building."

THE STEEL SKELETON CONSTRUCTION OF A TALL OFFICE BUILDING.

By J. S. Branne, Assoc. Mem. A. S. C. E.; Member of the Engineers' Club of St. Louis.

[Read before the Club, November 7, 1900.*]

The tall, skeleton construction building originated when the modern city grew very large, so that the price of land in the business heart of the city became very high, and in some cases the land to be had was limited. Not being able to expand the building horizontally, it became necessary to increase the number of stories. Up to seven or eight stories, stone or brick walls were used; but when it became necessary to put up a building of, let us say, fifteen stories, it was found very expensive to make such walls of sufficient thickness to sustain the superincumbent load; and the thick walls occupied too much space. Iron, being capable of sustaining a much greater load per square inch than stone or brick, was then introduced as columns, either cast or wrought, carrying the floor loads, and relieving the walls. Afterward a system of wall girders was introduced at each floor, to carry the story height of stone or brickwork, making each story self-supporting and carrying the entire load, through the columns, to the footings or foundations. The walls in all the stories could now be made of the minimum thickness, giving the maximum floor space for each story. The footings for the columns were at first made of stone or brick masonry resting on the soil, where this was solid; and on piles, where soft soil or even quicksand was encountered. Gradually the stone or brick masonry in the footing disappeared, giving way to steel and concrete, developing into our present-day grillage footings, of various kinds to suit various conditions. As the skeleton constructions grew taller, and the wall thicknesses decreased, making the entire structure lighter, the attention of architects and engineers was called to the necessity of giving stability against the overturning tendency of wind. This has been found to be a difficult matter. It is sometimes accomplished by rod-bracing, where this is permissible; in other cases, by horizontal girder construction and knee-braces; and sometimes by regular portal construction between adjoining columns. At present the use of iron in tall building construction has almost disappeared, giving way to steel, which now combines cheapness and strength.

*Manuscript received December 12, 1900.—Secretary, Ass'n of Eng. Socs.

The usefulness of the tall office building is apparent to all. The business or professional man on the ground floor can easily and quickly reach the one in tenth or twentieth story; offices can be had in the most desirable locations of the city at comparatively low rent. Very often certain trades or professions flock to certain buildings, where those engaged in them can easily reach each other for consultation.

We now proceed to illustrate the steel skeleton construction of high office buildings; how the steel work is planned, for a certain width, length and height of a building, and, for a certain lay-out of the buildings, to suit the purposes and ideas of the owner and architect, so as to combine strength and economy.

Under economy it is well to note that quite often the problem is of such a character that a theoretical economy of steel cannot be obtained. For instance, the columns must stand at certain places to

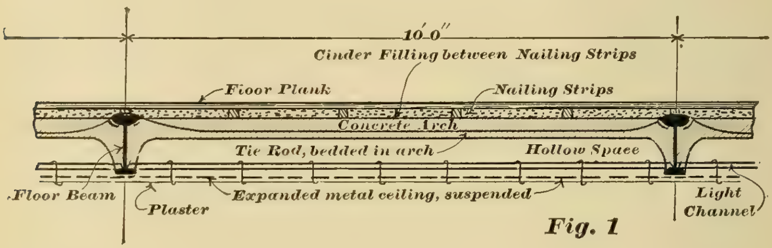


Fig. 1

suit the interior space arrangement of the building, or the irregularities of the lot and the surroundings. Thus more restrictions are laid upon the structural engineer than upon the bridge engineer, who can, generally may, consult only economy in determining the depth of truss or girder, the section of the various members and the spacing of towers or bents in viaducts. To the structural engineer many of these features are laid down in advance; even to the depth of the floor beams, where a few inches in each floor amount to something considerable in a building of several stories.

In the following paper a certain size of building has been chosen and the steel work for it has been determined. By thus referring to a definite set of plans and elevations, each class of work treated can be clearly itemized. Fig. A, Plate 1, shows the front elevation of the building adopted for this paper. The lot is 50 x 100 feet, and the building is 16 stories high in front and 13 stories in rear. The basement is 12 feet deep in front and 15 feet in rear, where the heating and lighting apparatus and the elevator plant are placed. The first story is 17 feet high, and all the

other stories 12 feet high, from floor line to floor line. All the curtain walls (outside walls in building) are 13 inches thick, and inside partitions 4 inches thick, built either of hollow tile or expanded metal furring on vertical channel studding, plastered on both sides. The floor is of concrete, of which several excellent styles are on the market. No shelf angles will be required on the webs of the floor beams, as the concrete will be built up from the flange of the beam to the springing line of the arch; and whatever ties are needed to keep the floor beams from spreading are imbedded in the concrete arch. (See Fig. 1.) Expanded metal ceilings, heavily plastered, suspended from light channels, rest on the bottom flange of the floor beams.

All deep floor girders and all interior columns (the wall columns have a brick inclosure) are protected by fire-clay tile, or other arrangement to keep off the flames in case of fire. The steel work in the foundations will have three or four coats of paint and then be bedded completely in cement to prevent rusting.

The following dead and live loads have been used:

Number of Floor.	Per Square Foot.			
	Live load.	Dead load.	Calculate Beams for	Calculate Girders for
Roof	30 lbs.	50 lbs.	80 lbs.	74 lbs.
Sixteenth floor to third floor	60 "	75 "	135 "	123 "
Second floor	60 "	90 "	150 "	138 "
First floor	100 "	90 "	190 "	170 "
Sidewalk	150 "	50 "	200 "	170 "

The following unit stresses have been used:

Bearing on soil, due to dead load, 2 tons per square foot. Bearing on soil, due to live load, 5 tons per square foot.

Rolled beams, tension or compression flange, 16,000 pounds per square inch.

Built girders (plates and angles), tension flange, 13,000 pounds per square inch; compression flange same as tension flange. Shear across web, 7500 pounds per square inch.

Z-bar columns, 12 feet long, compression 12,000 pounds per square inch for concentric and eccentric loads.

Z-bar columns, 15 and 17 feet long, 12,000 pounds concentric and 10,000 pounds eccentric.

Shop rivets, 10,000 pounds shear and 20,000 pounds bearing.

Field rivets, 7500 pounds shear and 15,000 pounds bearing.

Brickwork assumed to weigh 125 pounds per cubic foot. For wind load allow 33 per cent. higher values for columns and 50 per cent. higher values for wind-bracing girders.

The steel work for this building is divided into several classes, each of which, so far as possible, will be treated separately.

1. Foundations.
2. Floors.
3. Columns.
4. Wind bracing.
5. Typical details.

I. FOUNDATIONS.

Fig. C, Plate 1, shows the general arrangement of foundation grillage beams under columns marked No. 1 to No. 30, inclusive.

Before determining the size of any footing, the soil should be tested by digging or drilling to a depth of 20 feet below the deepest point of the proposed foundation. If, unfortunately, quicksand or soft soil is met with, piles must be driven. Old wells, in otherwise good soil, can be filled with broken stone and concrete well tamped. In the present paper the assumption is that good, solid soil was found, capable of resisting a dead load (weight of steel work, floors and walls) of 2 tons per square foot, without appreciable settlement. In this case the only obstacle was that the owners of adjoining buildings would not allow their walls to be underpinned, so that the footings for the wall columns of this building could be built partly on the other side of the lot line. This necessitated the introduction of cantilever girders between the following columns:

1 to 4	13 to 14	19 to 20
2 " 5	15 " 16	21 " 22
3 " 6	17 " 18	23 " 24

In determining the size of a footing, the influence of the dead load, always present, and that of the live load, variable in general and again variable as to wall columns and interior columns, should be considered separately. For example:

Column No. 2.

Dead load = 244 tons
Live load = 54 tons
} Total, 298 tons; at 2 tons per square foot, this will give 149 square feet (size of footing).

Live load removed, pressure per square foot will be 244 ÷ 149 = 1.64 tons, a decrease of 18 per cent.

Column No. 11.

Dead load = 295 tons
Live load = 111 tons
} Total, 406 tons; at 2 tons per square foot, this will give 203 square feet (size of footing).

Live load removed, pressure per square foot will be $295 \div 203 = 1.45$ tons, a decrease of 22½ per cent.

Clearly, in the long run, column No. 2 will settle more than column No. 11.

The writer proposes to give different values for live and for dead loads. In this case 2 tons have been used for dead loads and 5 tons for live loads.

Column No. 2 will then have $244 \div 2 + 54 \div 5 =$ about 133 square feet (size of footing); per square foot 2.24 tons.

Live load removed, pressure per square foot will be $244 \div 133 = 1.83$ tons, a decrease of 18 per cent.

Column No. 11 will then have $295 \div 2 + 111 \div 5 =$ about 170 square feet (size of footing); per square foot 2.39 tons.

Live load removed, pressure per square foot will be $295 \div 170 = 1.75$ tons, a decrease of 27 per cent.

Grouping the results in tabular form, we have:

DEAD AND LIVE LOADS AT 2 TONS PER SQUARE FOOT.

Column Number.	Pressure per Square Foot, due to Dead and Live Loads.	Pressure per Square Foot, due to Dead Loads only.	Difference in Pressure.
2	2 tons	1.64 tons	
11	2 "	1.45 "	0.19 tons

DEAD LOADS AT 2 TONS, LIVE LOADS AT 5 TONS PER SQUARE FOOT.

Column Number.	Pressure per Square Foot, due to Dead and Live Loads.	Pressure per Square Foot, due to Dead Loads only.	Difference in Pressure.
2	2.24 tons	1.83 tons	0.15 or
11	2.39 "	1.75 "	0.08

The maximum difference in pressure on soil, due to two different columns at one and the same time, evidently occurs when the dead and live loads are treated alike, and when only the dead loads act. Where different allowances are made for dead and for live loads, there is less *difference* between the pressures on the soil, caused by two columns at the same time.

It has been urged by some engineers that it would be more reasonable to consider dead loads only, and to figure so low a pressure per square foot of soil that the added live load would but slightly increase the pressure, thus reducing the differences between the pressures exerted by various columns at the same time.

As a general rule, the pressures exerted by interior columns fluctuate more than those of wall columns, the latter having to carry the constant wall load in addition to the concrete floors;

whilst the interior columns carry only the concrete floors, and are therefore more greatly affected by the live load.

Example 1. Footing Under Column No. 11.

Dead load = 295 tons; 295 ÷ 2 = 148 } Total, 170.
Live load = 111 tons; 111 ÷ 5 = 22 (about) } (Square feet.)

Pier outline 13 feet by 13 feet.

Beams in lower layer are placed 20 inches apart, requiring 9 9-inch beams, 21 pounds per foot, 12 feet 6 inches long.

Beams in middle layer are placed 15 inches apart, requiring 7 18-inch beams, 55 pounds per foot, 13 feet 4 inches long.

Beams in top layer are placed 9 inches apart, requiring 3 20-inch beams, 65 pounds per foot, 7 feet 6 inches long.

These beams are figured by finding out how much pressure per lineal foot comes on each, by dividing the column load by the number of lineal feet in each layer. One end is fixed, the other end is free and the load is uniform. The beams are held together by ¾-inch round tie rods, and properly spaced by gas pipe separators. The concrete should completely fill the spaces between the beams, and surround them at least 6 inches beyond their extreme ends, to prevent rusting.

Example 2. Footing Under Columns 2 and 5.

This is a case where, if the footing under column No. 2 were placed symmetrically, it would extend under the neighbor's wall; but, as this is not permitted, a cantilever girder has been placed, reaching from column No. 2 to column No. 5, as shown on plan No. 3.

The loads from column No. 2 are as follows:

Dead load, 244 tons; live load, 54 tons; total, 298 tons. Placing the center of bearing of footing No. 2 5 feet from lot line, we have:

$298 \times 19 = V \times 14$; $V = 404$ (tons), where V = the reaction at footing No. 2.

$298 \times 5 = V_1 \times 14$; $V_1 = 106$ (tons), where V_1 = the reaction at column No. 5.

Further considering footing No. 2, we have:

Pressure to provide for 404 tons, of which 330 tons are due to dead load and 74 tons are due to live load.

330 ÷ 2 = 165 }
74 ÷ 5 = 15 (about) } Total, 180 square feet.

We find, according to plan, a lower layer of 7 beams, 12-inch, 31½ pounds; a middle layer of 7 beams, 15-inch, 42 pounds, and a top layer of 4 beams, 20-inch, 65 pounds.

Further considering footing No. 5, we have:

Column load, 279 tons. Subtracting the upward reaction (produced by column No. 2) = 106 tons, we have only to provide for 173 tons, of which 120 tons are dead load and 53 tons live load. $120 \div 2 = 60$; $53 \div 5 = 11$ about. Total, 71 square feet. We find, according to plan, a lower layer of 7 beams, 9-inch, 21 pounds, 7 feet long, and an upper layer of 4 beams, 15-inch, 42 pounds, 10 feet long.

Note that the "live load" referred to in this class (1) includes 75 per cent. of the reactions produced in the columns by the wind pressure on the building (see Class 4). This ratio corresponds to the one used in proportioning the columns (see Class 3).

Cantilever Box-Girder.

This girder rests on footing No. 2 and footing No. 5, and transmits the load at column No. 2 to these two footings. The girder is made of 2 48-inch web plates, 3 24-inch cover plates on top and 3 on bottom, and 24-inch end cover plates, forming a complete box. At the points of loading, diaphragms are introduced for the sake of stiffness (see plan, elevation and section of girder, 2-5, Fig. D, Plate 1). It will be seen that the maximum bending moment occurs at the center of footing No. 2; that the shears are constant from column No. 2 to footing No. 2 and from column No. 5 to footing No. 2.

The cantilever is a very expensive feature of the building and should be avoided; and every effort should be made to obtain permission to underpin and build individual footings under adjacent walls.

2. FLOORS.

The construction of the several floors and for the roof at 13th floor level, and that of the roof over the 16th story, are shown on plans, while the "architect's plans," or those of the various floors, showing the arrangements of walls, windows and doors, stairways, elevators, etc., are shown on plans. The most important floor is the "typical office floor," Fig. F, Plate II, there being 10 such in this building,—viz, the 3d to the 12th floor, inclusively. As noted, the loads assumed were as follows:

Live load, 60 lbs. per square foot. *Dead load,* 75 lbs. per square foot.	*Beams* figured for 135 lbs. per square foot.	*Girders* (carriers supporting two or more beams). Dead load + 80 per cent. of live load = 123 lbs. per square foot.

The wall girders carry the floor loads plus the wall loads, and the latter are assumed at 125 pounds per superficial square foot. The walls are 13 inches thick. The walls, being cut up by windows, use 75 per cent. of a solid wall contained in panel over wall girder. In the case of the back wall, where there are few or no windows, use the entire wall, as though solid. Figure walls, on this basis, as uniformly loading the wall girders.

As to live loads, taken at 60 pounds per square foot, these consist of office furniture of various kinds, and human loads. Regarding the latter, Professor Burr, in his treatise on bridge and roof trusses, states that on a highway bridge a dense crowd of people will produce a load of 85 pounds per square foot. The late Mr. Hatfield, of New York city, found by experiment that it was hardly possible to exceed 70 pounds per square foot. Professor Merriman says that for highway bridges anywhere from 70 to 100 pounds per square foot may be taken. In an office building such a crowd can hardly be placed on each and every square foot. Considering desks, chairs, etc., it is the writer's opinion that 60 pounds are quite sufficient.

As to dead loads, we have a concrete arch of an average thickness of 4 inches, a filling between nailing strips of 1 inch, a plastered ceiling 1 inch thick; total, 6 inches, of an average weight of 80 pounds per cubic foot, or 40 pounds per square foot. Add to this nailing strips and flooring (7/8 inch thick), weighing 10 pounds per square foot. The weight of the partitions, in a 12-foot story, divided into offices as noted on plan No. 11, amounts to 15 pounds per square foot of floor. The weight of steel construction, 10 pounds per square foot of floor.

SUMMARY.

Concrete floor and plastered ceiling......	40 lbs. per square foot.
Nailing strips and flooring...............	10 " " " "
Partitions...............................	15 " " " "
Steel construction.......................	10 " " " "
Total	75 lbs. per square foot.

The assumption that the girders, in the sense used here, are safe at 80 per cent. live load presupposes that all the beams framing into the girders have not their full live loads at the same time.

Considering a typical panel, as, for instance, that between columns Nos. 5, 6, 9 and 8, it will be found by trial that the most economical system requires 10-foot arches as shown on Fig. E, Plate II. This gives 12-inch, 31½ pounds floor beams, and 15-

COLUMN SCHEDULE, IN INCHES.

NUMBER OF COLUMN.

No. of Story.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
16	....	....	....	....	....	....	....	....	....	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼
15	....	....	....	....	....	....	....	....	....	8 x ¼	"	8 x ¼	8 x ¼	8 x ¼	"
14	....	....	....	....	....	....	....	....	....	"	8 x ¼	"	"	"	8 x ¼
13	....	....	....	....	....	....	....	....	....	8 x 5/16	"	8 x ¼	8 x ¼	8 x ¼	"
12	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	"	8 x ½	"	"	"	8 x ¼
11	"	8 x ¼	"	8 x ¼	"	8 x ¼	"	8 x ¼	"	8 x ½	"	8 x ⅜	8 x ¼	8 x ¼	"
10	8 x ¼	"	8 x ¼	"	8 x 5/16	"	8 x ⅜	"	8 x ⅜	"	10 x ⅝	"	"	"	8 x ⅜
9	"	8 x ⅜	"	8 x ½	"	8 x ½	"	8 x ⅜	"	10 x ⅝	"	8 x ½	8 x ¼	8 x 5/16	"
8	8 x 5/16	"	8 x 5/16	"	8 x ½	"	8 x ⅝	"	8 x ⅝	"	12 x 11/16	"	"	"	8 x ½
7	"	8 x 9/16	"	10 x ⅝	"	10 x ⅝	"	8 x 9/16	"	12 x 13/16	"	10 x 11/16	8 x 5/16	8 x ⅜	"
6	8 x ½	"	8 x ½	"	10 x 9/16	"	12 x 11/16	"	12 x 11/16	"	12 x ⅞	"	"	"	8 x 9/16
5	"	10 x 11/16	"	12 x 13/16	"	12 x 11/16	"	10 x 11/16	"	12 x 11/16 2-14 x 9/16	"	12 x 13/16	8 x ⅜	8 x ½	"
4	8 x ⅝	"	8 x ⅝	"	12 x ⅝	"	12 x ⅞	"	12 x ⅞	"	12 x 11/16 2-14 x ⅝	"	"	"	8 x 11/16
3	"	12 x ¾	"	12 x 11/16 2-14 x 9/16	"	12 x 11/16 2-14 x 9/16	"	12 x 11/16	"	12 x ⅞ 2-14 x 11/16	"	12 x ¾ 2-14 x 7/16	8 x 7/16	8 x 9/16	"
2	12 x ⅝	"	12 x ⅝	"	12 x 13/16	"	12 x 11/16 2-14 x 13/16	"	12 x 11/16 2-14 x 13/16	"	12 x 13/16 2-14 x 11/16	"	"	"	10 x 11/16
1	"	12 x 11/16 2 pl-14 x ⅜	"	12 x 13/16 2-14 x ⅞	"	12 x 13/16 2-14 x ⅞	"	12 x ⅞	"	12 x ⅞ 4-14 x 9/16	"	12 x ⅞ 2-14 x ⅞	8 x ½	8 x ⅝	"
Basement.	12 x ¾	"	12 x ¾	"	12 x ⅞	"	12 x 13/16 2-14 x ⅞	"	12 x 13/16 2-14 x ⅞	"	12 x 13/16 2-14 x ⅞	"	"	"	10 x ¾

No. of Story.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	No. of Story.
16	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	....	....	....	....	....	....	16
15	8 x ¼	8 x ¼	"	8 x ¼	"	"	8 x ¼	"	8 x ¼	....	....	....	....	....	....	15
14	"	"	8 x ¼	"	8 x ¼	8 x ¼	"	8 x 5/16	"	....	....	....	....	....	....	14
13	8 x ¼	8 x ⅜	"	8 x 5/16	"	"	8 x ⅜	"	8 x 5/16	....	....	....	....	....	....	13
12	"	"	8 x 7/16	"	8 x 7/16	8 x 7/16	"	8 x ½	"	....	....	....	....	....	....	12
11	8 x ¼	8 x 9/16	"	8 x ½	"	"	8 x 9/16	"	8 x ½	....	....	....	....	....	....	11
10	"	"	8 x 9/16	"	10 x 9/16	8 x ⅝	"	10 x 9/16	"	....	....	....	....	....	....	10
9	8 x ¼	10 x ⅝	"	8 x 11/16	"	"	10 x ⅝	"	10 x ⅝	....	....	....	....	....	....	9
8	"	"	10 x 11/16	"	10 x ¾	10 x 11/16	"	10 x ¾	"	....	....	....	....	....	....	8
7	8 x 5/16	10 x 13/16	"	10 x ¾	"	"	12 x 11/16	"	12 x 11/16	....	....	....	....	....	....	7
6	"	"	12 x 11/16	"	12 x 13/16	12 x ¾	"	12 x 13/16	"	....	....	....	....	....	....	6
5	8 x ⅜	12 x 11/16 2-14 x ⅜	"	12 x 13/16	"	"	12 x ⅞	"	12 x 11/16	....	....	....	....	....	....	5
4	"	"	12 x ⅞	"	12 x 11/16 2-14 x 9/16	12 x ⅞	"	12 x 11/16 2-14 x 7/16	"	....	....	....	....	....	....	4
3	8 x 7/16	12 x 11/16 2-14 x 11/16	"	12 x 13/16 2-14 x ⅜	"	"	12 x 11/16 2-14 x 9/16	"	12 x 11/16 2-14 x ½	....	....	....	....	....	....	3
2	"	"	12 x 11/16 2-14 x ½	"	12 x ⅞ 2-14 x 9/16	12 x 11/16 2-14 x 11/16	"	12 x 11/16 2-14 x ¾	"	....	....	....	....	....	....	2
1	8 x ½	12 x ⅞ 2-14 x 13/16	"	12 x 11/16 2-14 x 11/16	"	"	12 x 13/16 2-14 x 13/16	"	12 x ¾ 2-14 x ⅞	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	8 x ¼	1
Basement.	"	"	12 x 11/16 2-14 x 11/16	"	12 x ⅞ 2-14 x 13/16	12 x ¾ 2-14 x ⅞	"	12 x 13/16 2-14 x 13/16	"	"	"	"	"	"	"	Basement.

inch, 60 pounds floor girders. An 18-inch, 55 pounds beam would be equally cheap, and stiffer, but its use would involve the loss of 3 inches of head room, amounting to 3 or 4 feet in the entire building. In designing floor beams and girders, the deflection must be taken into account. If the deflection amounts to more than $\frac{1}{360}$ of the span, it is apt to crack a plastered ceiling. However, it must also be remembered that, when plaster is applied, all the dead load is already in place, and has produced its deflection, so that we have to consider only the deflection due to the live loads. The deflection of a symmetrical shape, for example, a beam, is

For uniform loading $\frac{5Wl^3}{384.E.I}$

For loading concentrated $\frac{Pl^3}{48.E.I}$

at center, where

W = total uniformly distributed load in pounds.

P = total concentrated load in pounds.

l = length of beam in inches.

E = modulus of elasticity (for medium steel E = 29,000,000 pounds).

I = moment of inertia.

If W = 2P (equal maximum bending moments), the deflection under the concentrated load is only 80 per cent. of that under the uniform load.

The wall girder (6-9) will be made of an 18-inch, 55 pounds beam and a 12 x $\frac{5}{16}$-inch plate riveted to its top flange, giving a good bearing for the 13-inch wall. This plate should be riveted to the beam, thereby increasing its inertia. In the case of another wall girder (20-24), in addition to the top plate, a bottom plate is riveted on, over half the length of the beam. This effects a saving in material; as, by merely giving the 12 x $\frac{5}{16}$-inch top plate bolts to hold it in position, a 20-inch, 650 pounds beam would be required; and coming under the same price classification (fitted beams). (See Figs. 2 and 3.)

Beams at stair landings are figured as though the stairs were fully loaded. Beams at elevator openings are strong enough to carry the regular floor loads, and, in addition, a slight weight due to the elevator inclosures, guides, etc.

It will be noted that the transverse beams between columns are built of plates and angles, serving at the same time as wind-bracing girders, under which class they will be treated later on.

Whatever has been said about the typical office floor refers, with slight variations, to all other floors.

The first floor is figured for a live load of 100 pounds per square foot, and a dead load of 90 pounds per square foot. This increase of live load, as compared with typical office floor, is due to the fact that more persons are liable to congregate on a floor devoted to store purposes than on an office floor. Add to this the sometimes heavy loading of dry goods, counters, etc.

The increase in dead load is due to an extra heavy flooring for store room. The beams in the sidewalk are figured for 200 pounds per square foot, dead and live loads.

The second floor is figured for a live load of 60 pounds per square foot, and a dead load of 90 pounds per square foot, due to a marble ceiling over the first story. It will be noticed that the light court commences here, taking in the space between columns Nos. 4, 14, 13, 25 on one side and 6, 15, 16, 28 on the other.

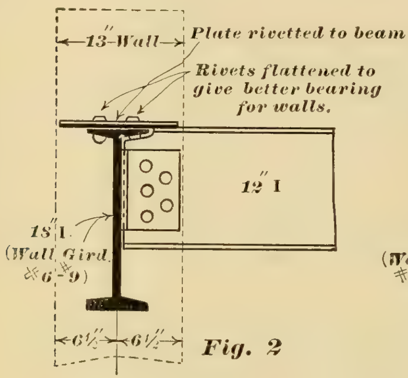


Fig. 2

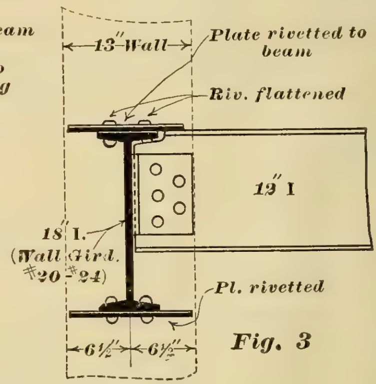


Fig. 3

These spaces are finished with glass, in which is imbedded ¾-inch mesh steel wire netting, laid between tees 24 inches apart on centers.

The thirteenth floor is really, in part, a sloping roof, for rear of building, between columns 1, 3, 12 and 10, and, in part, a regular floor, between columns 10, 21, 24 and 12. The roof is figured for a live load of 30 pounds and a dead load of 50 pounds per square foot. The floor is figured for the same loads as the typical office floor. The roof slopes toward the rear ¾ inch per foot. The roof is formed by spanning concrete arches between beams, and giving to the surface several coats of asphalt and gravel.

The fourteenth, fifteenth and sixteenth floors are like the thirteenth floor.

The roof, over the sixteenth story, between columns 10, 21, 24, 12, is made like the one at thirteenth floor level between columns 1, 3, 12 and 10. On the roof is a dog house, or a brick inclosure,

12 feet high, located over elevators and main stairway, and covered with a slate roof. The purpose of this little house is to give a covering for the elevators, with head room enough to place sheaves and other fixtures for the elevator cars; also to give an exit to the roof, thus terminating the main stairway in a fireproof door leading to the roof at the very front of the building; and, extending for a few feet to each side, toward the rear, is a 5-foot projection for a terra cotta cornice. The terra cotta will be carried by 4-inch beams, 30 inches apart, again carried by main girders 21 to 24 and 8-inch beams parallel to the girders. The method of connecting the floor beams and the girders to the columns is shown in Fig. H, Plate III, of "General Details." Beam is connected to beam by "connection angles," standardized by leading manufacturers into 6 or 7 different kinds to suit all sizes of beams and channels. These connections are designed for the largest loads that can be expected on the ordinary spans of beams. All connections should be riveted.

3. COLUMNS.

The columns carry the entire weight, including dead and live loads, and the wind pressure, into the footings, these again distributing said loads on the soil. The aim, as explained under footings, is to have an equal pressure per square foot of soil at the same time for all footings, insuring an even settlement. The columns adopted in this building are "Z-bar columns" (Fig. 4), very extensively used of late years; they are made of 4 Z bars and 1 web plate. Where this section will not suffice, extra plates are riveted on, forming a closed column. Where the closed column occurs, all the paint specified should be applied before riveting up or assembling. The columns rest either on the top layer of grillage beams in the footings, or on cantilever girders, to which latter they should be riveted, if possible; and, if not, bolted. The cantilever girders are 24 inches wide, and the grillage beams of the top layer are spaced 9 inches on centers; thus all base plates can be made 24 by 24 inches and ¾ inch thick. The columns are joined, one section on top of the other, in such a manner as to secure an equal and complete transmission of loads from story to story and finally into the footings. Fig. H, Plate III, shows a typical column splice, a 10-inch column resting on a 12-inch column. The top of the lower and the bottom of the upper column are planed, and a ½-inch butt plate is placed between them. Then there are vertical splice plates, ⅜ inch thick, and fillers to make up the different widths of shafts. Generally the column shaft is spliced at every other floor, and the adjacent columns must break joints; that is, they must not be

spliced at the same floors. For instance, column No. 7 is spliced at the third, fifth and seventh floors, etc.; then columns Nos. 4 and 10 are spliced at the fourth, sixth and eighth floors, and so on. This is supposed to add to the stiffness of the structure, whereas it renders the erection more difficult. For intermediate columns, connections for beams and girders are generally concentric, but for wall columns this is rarely possible, as the latter must be set in far enough from the face of the wall to get at least one brick thickness outside; while wall girders are located at centers of walls. Any one of the floor plans will illustrate this, and detail plans Nos. 13 and 14 show connections in detail. Fig. H, Plate III, shows concentric connections of 15-inch floor girders, beams resting on bracket and held on top by angle lug. Fig. I, Plate III, shows connections to column No. 15 at sixth floor, where wall girders are 6½ inches eccentric with column.

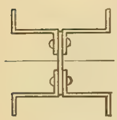


Fig. 4

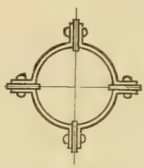


Fig. 5

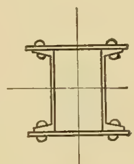


Fig. 6

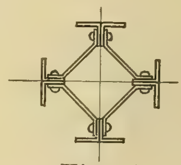


Fig. 7

As to the proportioning of the columns, the following rules have been used:

(a) Proportion for entire dead load.

(b) Proportion for live load according to a "sliding scale," giving top story or attic columns full load, and basement columns 80 per cent. of all the live loads carried into them. For intermediate stories interpolate; thus, in a 16-story building, a sixth-story column would be proportioned for 88 per cent. of all live load above that floor. This is an entirely arbitrary ratio, and is recommended by the St. Louis Architectural Club, and incorporated into the building laws of St. Louis, dated August 1, 1898. It is based on the supposition that all floors are not at the same time loaded to the extent specified. As to permissible stress per square inch, for medium steel 12,000 pounds has been used for both concentric and eccentric loading for short columns (12 feet). For longer columns, use 10,000 pounds, in order to allow for eccentric loading. For wind load, raise the values by 33 per cent.,—that is, use 16,000 pounds or take 75 per cent. of the wind loads and use 12,000 pounds. See also (4) "Wind Bracing," below. Note that the eccentric loading does not accumulate downward through the build-

ing. Hence, all the eccentric loading carried by any one column is simply whatever load is brought into it at the floor immediately above. Thus, for large columns, the eccentric loading has a relatively smaller influence, the inertia of the section being large.

Other column sections quite frequently used are the "Phœnix" column (Fig. 5) and ordinary channel columns (Fig. 6) (composed of 2 channel bars, or of channels and plates). The "Gray" column (Fig. 7), made of angles, and having its outline section constant from basement to roof, has been patented and considerably used. The writer, however, prefers the "Z" or the "Phœnix" column, because in them the loads are almost instantly transmitted into the entire body of column.

The accompanying schedule for Z-bar columns gives the size of each column, from basement to roof. Note how the column splices are staggered (or joints broken). The 8-inch column is the smallest used, smaller sections being more difficult to handle in the shop.

4. WIND BRACING.

The pressure, in pounds per square foot, for which a building should be calculated is very often fixed at 30, and is supposed to be applied to the entire surface, from sidewalk level to cornice. If the pressure be called P, and the velocity in miles per hour V, it has been claimed that

$$P = \frac{V^2}{200}$$

and also that
$$P = \frac{V^2}{100}$$

There is quite a difference in opinion between scientific men and engineers in regard to the relation between the velocity of the wind and the pressure it exerts on a vertical surface, of larger or smaller extent, and at a larger or smaller height; also as to the continuity of such pressure.

Mr. C. Shaler Smith, in his paper on "Wind Pressure upon Bridges," read before the American Society of Civil Engineers on December 5, 1880, cites a few examples of actual results, and then calculates what pressure could produce such results.

In a violent storm in 1871, a locomotive was overturned at East St. Louis. This feat represented a wind pressure of 93 pounds per square foot of actual surface.

He also cites numerous cases of car derailments when the pressure required would be 30½ pounds per square foot of actual surface. He gives, as a general opinion, that 30 pounds per square foot is enough for an average truss bridge (about 150 feet

long) as he knows of only one case where the path of the tornado was over 60 feet wide.

In the discussion of Mr. Smith's paper it was contended that anemometers had shown as high as 90 pounds pressure per square foot; and the opinion is expressed that this high figure may be caused by the shock, or impact of the oncoming storm.

The building code of New York city, adopted October 10, 1899, calls for 30 pounds horizontal wind pressure for every square foot exposed; also, that the overturning moment of the wind shall be equal to, or less than, 75 per cent. of the moment of stability of the structure. It further requires that "If the resisting moment of the ordinary materials of construction, such as masonry, partitions, floors, connections, are not sufficient to resist the moment of distortion due to wind pressure, in any direction," wind bracing must be put in. The building laws of St. Louis call for 30 pounds per square foot, from sidewalk level to extreme top of building.

It is well to note that, up to the fifth or sixth floor level, buildings generally are protected by adjoining or nearby structures. A building offers a large surface, and, according to most persons who have studied this subject, the large surface does not receive, over its entire extent, the intensity of pressure that a small surface receives. In the opinion of the writer, 30 pounds per square foot for the entire surface is enough for a building such as that described in this paper.

The best and cheapest method of bracing is by means of rods, running diagonally between columns, from top to bottom. But in most cases this is entirely out of the question, as it will interfere with free passage from room to room, and along the corridors. This is especially objectionable in the first story, which often is thrown into one room, as a store. Another method is to use a deep girder, with knee braces at the ends, connecting it with the columns, and relying on the resistance of the girders to bending. Again, knee braces quite often become undesirable when there is no convenient wall or partition to hide them, and in this latter case have been used plate girders, as deep as possible, connected to columns by enough rivets to transmit into columns the end shears due to wind loads and dead and live loads, and to resist the couple described later (see Fig. 9 or Fig. 12). This latter is the system used in this building, and is illustrated in Fig. J, Plate I, with a detailed connection to column shown in Fig. H, Plate III.

Fig. J, Plate I, shows the wind-bracing system between columns 4, 5, 6 or 7, 8, 9. The plate girders are 30 inches deep, up to

and including the sixth floor; while the remainder are only 24 inches deep. These girders act both as floor beams in their respective floors, and as wind-bracing girders. The connection to the Z-bar column is indicated in detail in Fig. H, Plate III. The gusset plates at the columns should be brought down if necessary below girder to get enough rivets. In a narrow building the columns should be so placed as to bring the web plate of the column perpendicular to the long axis of building. This makes easier and more direct connections between girders and columns. Sometimes the gusset plate is run through the column, forming part of it. In the present case connection angles are used, fastening the girders to the face of the column. This is more economical and requires

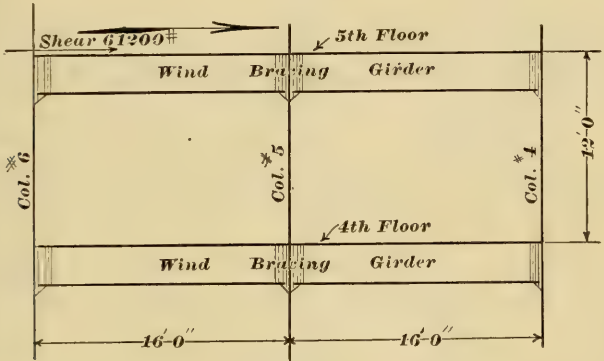


Fig. 8

one planed joint less. The method used for calculating sections of bracing girders is as follows, using system 4, 5, 6 as an illustration:

Find the wind load at each floor (being equal to number of square feet transferred into bracing system at floor multiplied by 30). If the question is to determine section of girder at fifth floor, add the wind load from roof to fifth floor, inclusive, amounting in this case to 61,200 pounds. (See Fig. 8.)

With the bracing girders properly riveted in place, the column system 4, 5, 6 is supposed to be rigid, so as to act as one piece, and so that all shears are ultimately carried into the footings, being transferred from the bracing girders at one floor through the columns, straining these on bending, to the girders at floor below and so on to base of columns. Referring now to Fig. 9, showing the bending moments, and to Fig. 10, showing the shears, the following notations have been used:

p = one-third of the total shear (horizontal) at fifth floor. (In this case $\frac{1}{3} \times 61{,}200 = 20{,}400$ pounds.)

V = the vertical reaction at column No. 4 or column No. 6.

H = the height of fourth story.

W = the distance, center to center, between columns No. 4 and No. 5, or between columns No. 5 and No. 6.

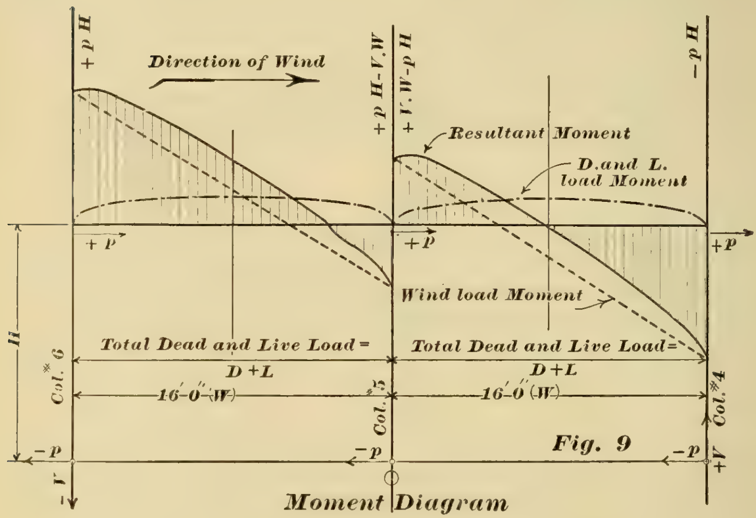
D = the total dead load on girder.

L = the total live load on girder.

Assuming the wind to blow in the direction of the arrow (refer to Fig. 9),

$$3.p.H - 2.V.W = O$$

$$V = \frac{3.p.H}{2.W}$$



If we now investigate the bending moments on girders connecting columns No. 4, No. 5 and No. 6, we find:

On the right side of column No. 6 + p.H. (Compression in top flange.)

On the left side of column No. 5 + p.H — V.W. (Tension in top flange.)

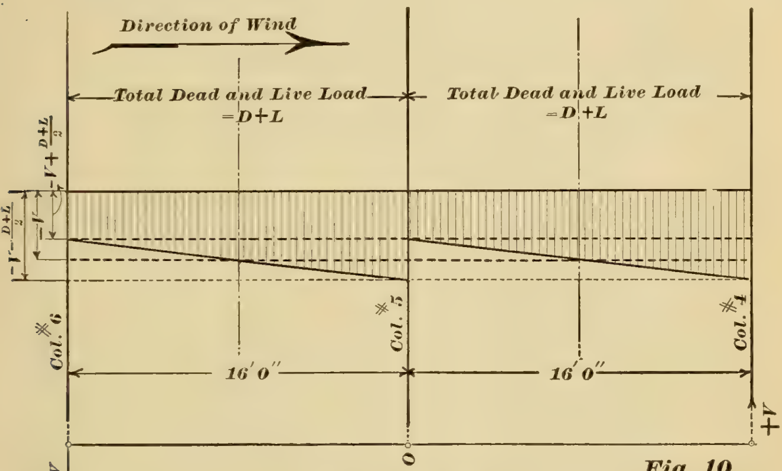
On the right side of column No. 5 — p.H + V.W. (Compression in top flange.)

On the left side of column No. 4 — p.H. (Tension in top flange.)

These are the extreme positive and negative moments on girders.

The bending moments due to the dead and live loads will have their maximum value at centers of girders $= \frac{(D + L)W}{8}$.

In Fig. 9 the bending moments due to wind are drawn with dotted lines, the bending moments due to dead and live loads are drawn with dot and dash lines, and the resultant moments with full lines. The ordinates in the shaded polygons will give the bending moment at any place along the top flange of girder. The bending moments along the bottom flange will be somewhat smaller, and generally of opposite sign.



Shear Diagram

Fig. 10

Assuming the wind to blow in the direction of the arrow (refer to Fig. 10), it will be seen that the vertical shear

On the right side of column No. 6 $= -V + \frac{D+L}{2}$

On the left side of column No. 5 $= -V - \frac{D+L}{2}$

On the right side of column No. 5 $= -V + \frac{D+L}{2}$

On the left side of column No. 4 $= -V - \frac{D+L}{2}$

Column No. 5 occupies the center of the building, and it has been assumed that this column causes neither a positive nor a negative vertical reaction. In proportioning girder, note that the extreme fiber stress has been raised by 50 per cent., 13,000 pounds being used for dead load and live load, and 20,000 pounds for wind load stresses; as the wind load stresses seldom occur, and taken altogether with the dead and live load stresses, the stress per square inch runs considerably below 20,000 pounds. The girders are also subject to direct compression (due to wind loads), but the writer thinks this compressive stress can be safely disregarded, as the con-

crete floor can be relied upon to carry this load, or to help in doing so.

The next tning to consider is the influence of the wind pressure on the columns. Considering system 4, 5, 6, Fig. J, Plate I, there is, at the roof, a wind load of 3600 pounds; at floors from the twelfth to the third, inclusive, 7200 pounds; at the second floor, 8700 pounds, and at the first floor, 5100 pounds.

The load on column 4 (or 6) caused by the wind will be:

Twelfth story $\dfrac{3600 \times 12}{32} = 1350$ pounds.

Eleventh story $\dfrac{10{,}800 \times 12}{32} + 1350 = 5400$ pounds.

Tenth story $\dfrac{18{,}000 \times 12}{32} + 5400 = 12{,}150$ pounds.

Ninth story $\dfrac{25{,}200 \times 12}{32} + 12{,}150 = 21{,}600$ pounds,

and so on, down to the footings.

In other words, the moments, due to wind loads, are found at each floor; the resultant moment divided by the distance, center to center, between outer columns, No. 4 and No. 6, will give the stress in columns No. 4 and No. 6, which evidently is tensile on the windward side and compressive on the leeward side. Column No. 5, being at the center of the building, will get no allowance for the wind loads. By an inspection of the shear diagram, Fig. 10, it will be noticed that the vertical shear, due to wind loads, is constant from column No. 6 to column No. 4. In proportioning columns, note that for stresses due to wind pressure, 16,000 pounds per square inch has been used, or 33 per cent. more than for dead and live loads.

The direct bending moments on columns due to wind loads have not been considered in proportioning these columns. By trials it was found that for a story height of 12 feet, and a width of building of 32 feet, these bending moments did not raise the fiber stress to any great extent. The influence of these direct bending moments should, however, be investigated for each separate design; as, for a very narrow building with high stories, it may become necessary to increase the amount of metal in columns.

The general treatment of the wind-bracing system between columns 17, 18, 19 and 20 is similar to that above described, but we now have four columns where before we had but three. (See Fig. 11.)

Fig. 11 shows columns 17, 18, 19, 20 at twelfth floor. The bracing girders are riveted in place, and the shear at twelfth floor

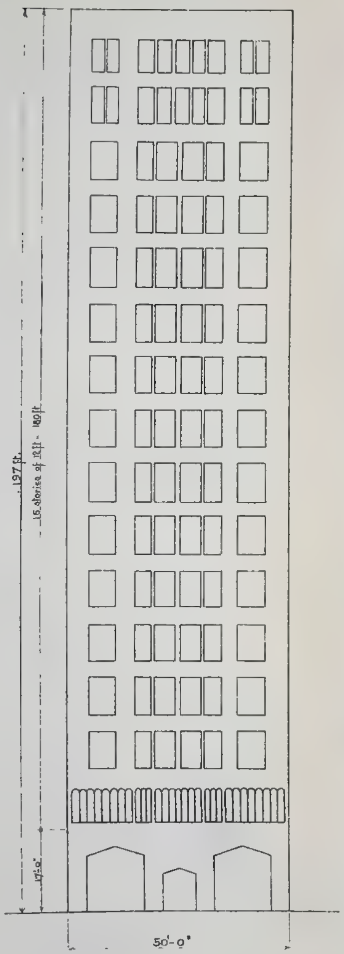


FIG. A. FRONT ELEVATION

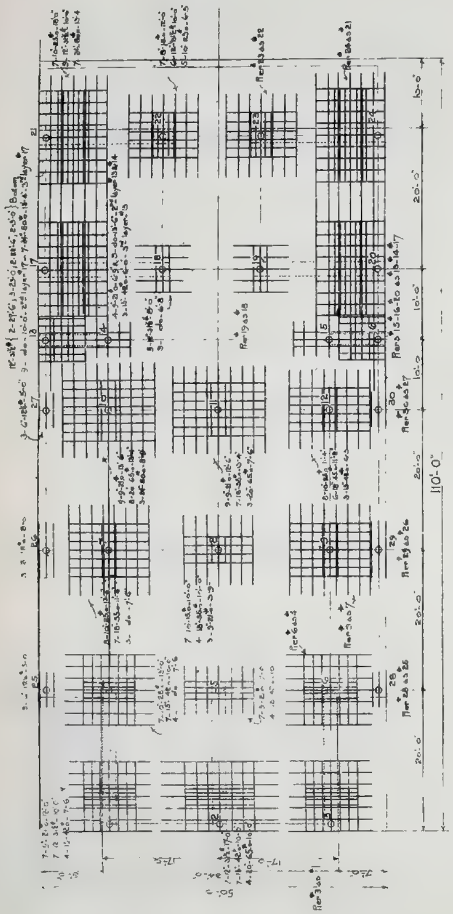


FIG. C. FOUNDATION PLAN.

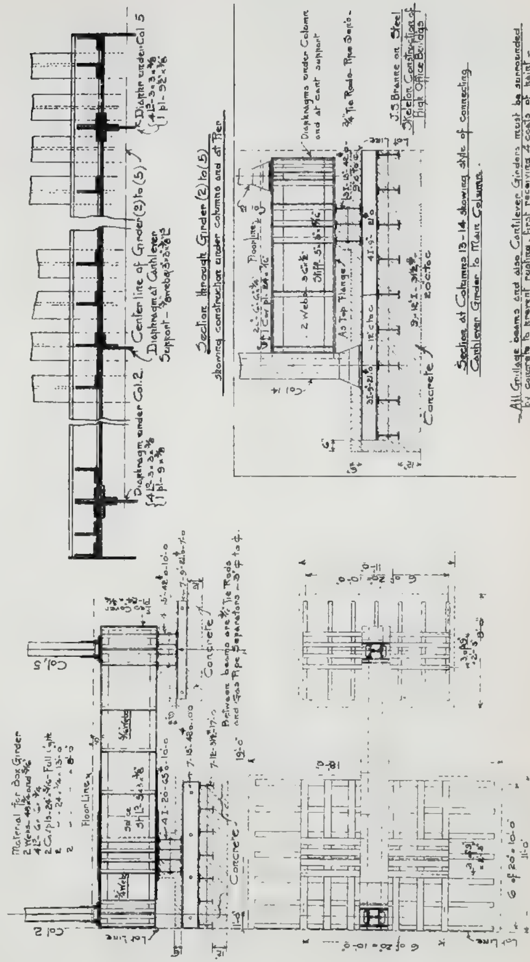


FIG. D. GENERAL DETAILS FOR FOUNDATIONS.

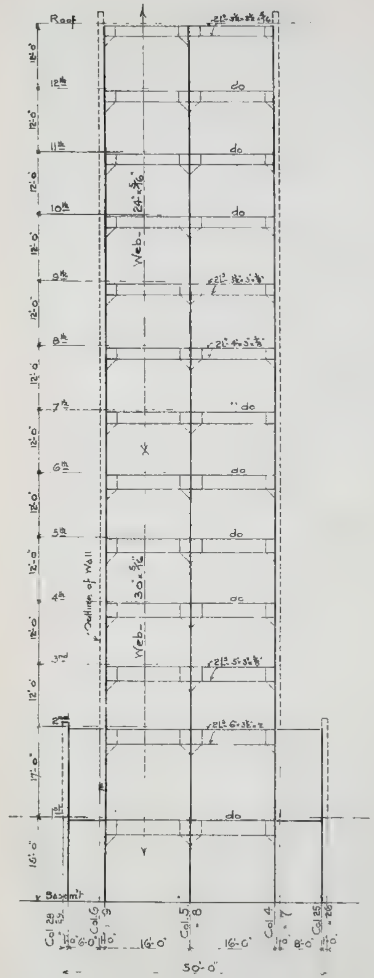


FIG. J. WIND-BRACING COLUMNS 4, 5, 6, OR COLUMNS 7, 8, 9.

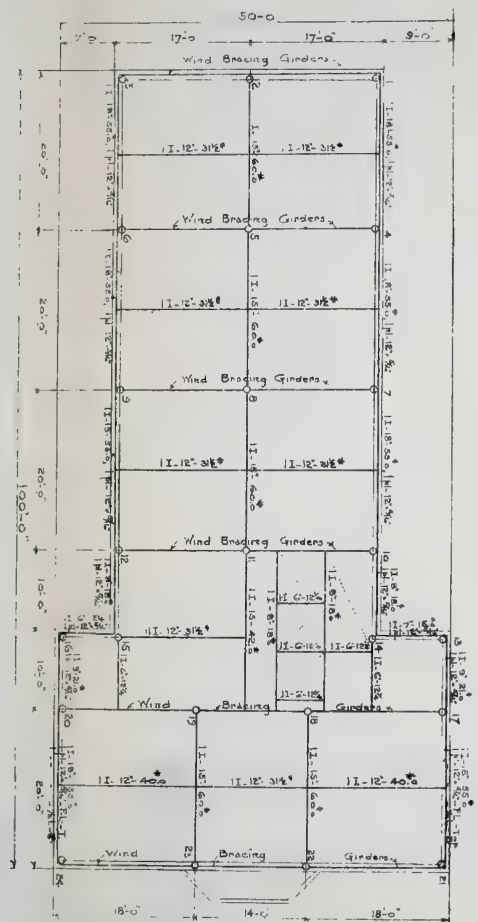


FIG. E. TYPICAL OFFICE FLOOR (3RD TO 12TH INCLUSIVE).

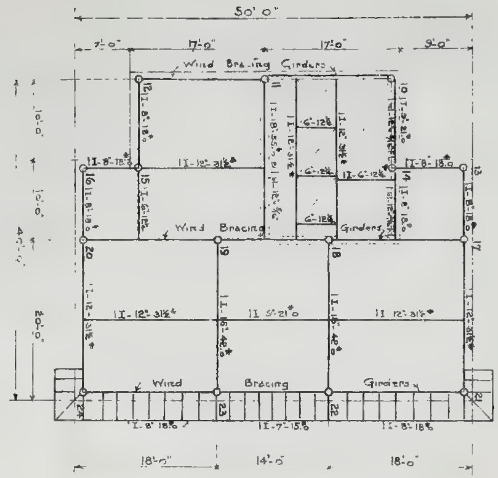
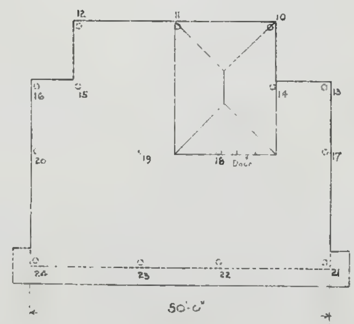


FIG. F. ROOF.



— Roof —

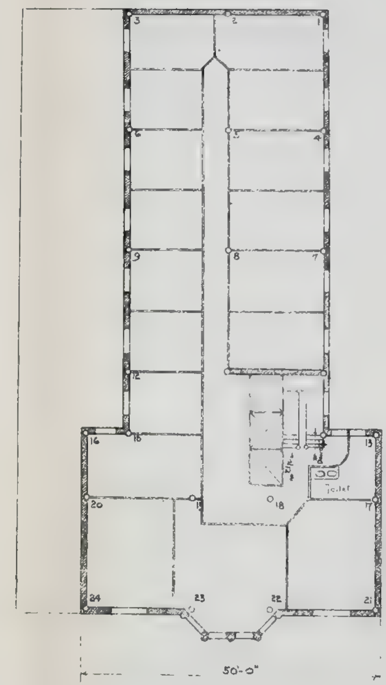


FIG. G. TYPICAL OFFICE FLOOR (3RD TO 12TH INCLUSIVE).

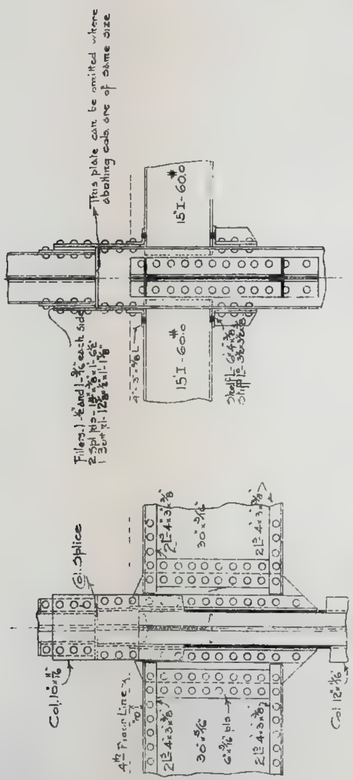
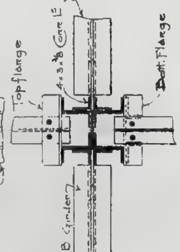



FIG. H. GENERAL DETAILS SHOWING CONNECTIONS OF WIND-BRACING GIRDERS AND FLOOR GIRDERS TO COLUMN No. 8 AT 4TH FLOOR.

NOTE. ALL CONNECTIONS RIVETED.

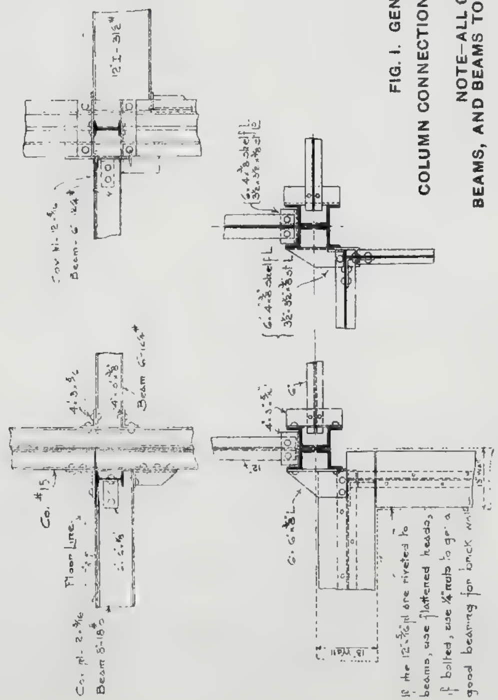


FIG. I. GENERAL DETAILS SHOWING COLUMN CONNECTION AT 6TH FLOOR. COL. 15.

NOTE—ALL CONNECTIONS, BEAMS TO BEAMS, AND BEAMS TO COLUMNS, ARE RIVETED.

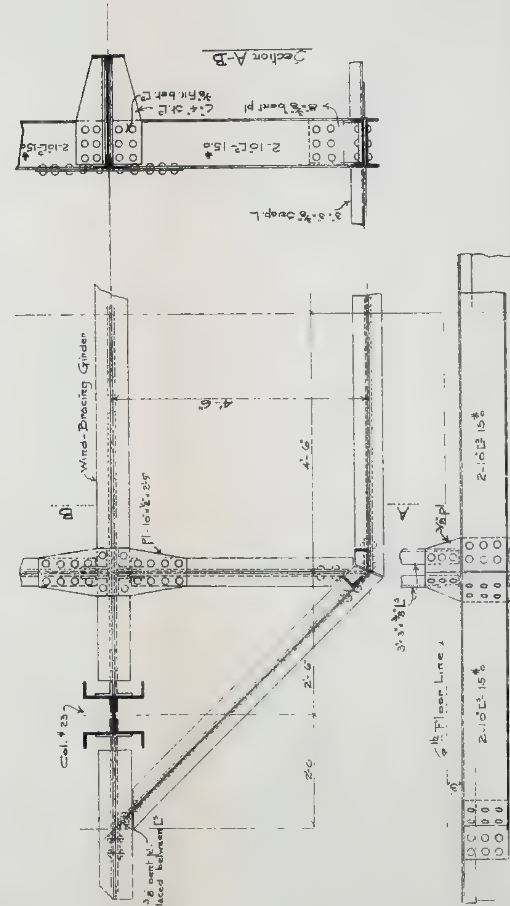


FIG. K. TYPICAL DETAIL OF BAY WINDOW FRAMING, SHOWING METHOD OF SUSPENSION (SIMILAR AT 15TH, 12TH, 9TH, 6TH & 4TH).

will be transferred from the bracing girders through the columns in eleventh story, straining these on bending, to the bracing girders at eleventh floor, and so on to the base of columns.

Referring now to Fig. 11 and to Fig. 12, showing the bending moments, and Fig. 13, showing the shears, the following notations have been used:

p = one-fourth of the total horizontal shear at twelfth floor (in this case ¼ × 39,600 = 9900 pounds).

X = the vertical reaction at column No. 17 or column No. 20.

Y = the vertical reaction at column No. 18 or column No. 19.

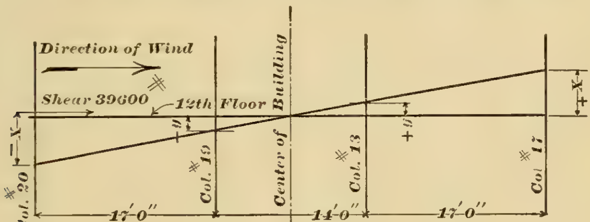


Fig. 11

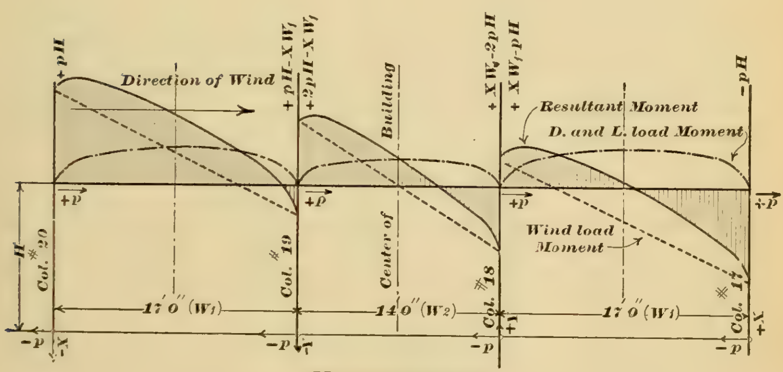


Fig. 12

H = the height of eleventh story.

W_2 = the distance, center to center, between columns No. 18 and No. 19.

W_1 = the distance, center to center, between columns No. 17 and No. 18, or No. 19 and No. 20.

D and L, D_1 and L_1, total dead and live load on girders. (Assumed uniform in order to simplify the treatment.) The center of the building lies halfway between columns No. 18 and No. 19; and it has been assumed that the strains in the columns, caused by wind loads, are proportional to the distance of column from center of building; or

$$X : Y = 24 : 7$$

$$X = \frac{24}{7}.Y \ldots\ldots\ldots\ldots (a)$$

Assuming the wind to blow in the direction of the arrow (refer to Fig. 12):

$$4.p.H - X(2W_1 + W_2) - Y.W_2 = O \ldots\ldots (b)$$

From equations a and b X and Y can be easily found.

If we now investigate the bending moments on girders connecting columns Nos. 17, 18, 19, 20, we find:

On the right side of column No. 20 $+ p.H$. (Compression in top flange.)

On the left side of column No. 19 $+ p.H - XW_1$. (Tension in top flange.)

On the right side of column No. 19 $+ 2.p.H - XW_1$. (Compression in top flange.)

On the left side of column No. 18 $- 2.p.H + XW_1$. (Tension in top flange.)

On the right side of column No. 18 $- p.H + XW_1$. (Compression in top flange.)

On the left side of column No. 17 $- p.H$. (Tension in top flange.)

These are the extreme positive and negative moments on girders.

The bending moments due to the dead and live loads will have their maximum value at centers of girders $= \frac{(D + L)W_1}{8}$ and $\frac{(D_1 + L_1)W_2}{8}$ for outer and inner girders respectively. The bending moments due to wind loads and dead and live loads are shown similarly to what was shown in Fig 9, and the resultant moments along top flange of girder can be scaled off; the moments along the bottom flange are slightly smaller and generally of opposite sign.

Assuming the wind to blow in the direction of the arrow (refer to Fig. 13), it will be seen that the vertical shear:

On the right side of column No. 20 $= - X + \frac{D + L}{2}$

On the left side of column No. 19 $= - X - \frac{D + L}{2}$

On the right side of column No. 19 $= - X - Y + \frac{D_1 + L_1}{2}$

On the left side of column No. 18 $= - X - Y - \frac{D_1 + L_1}{2}$

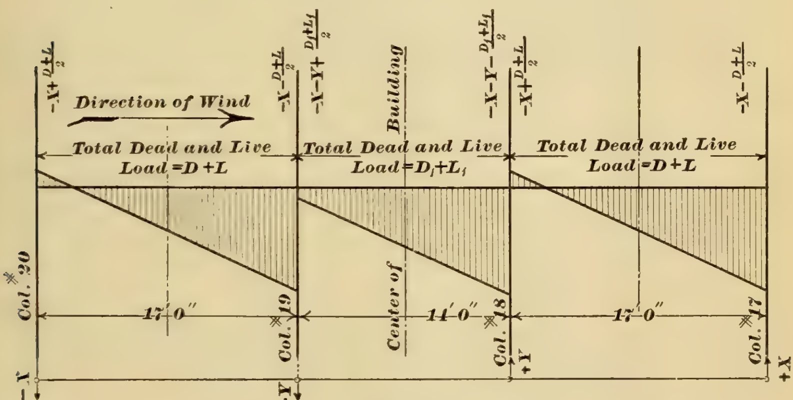
On the right side of column No. 18 $= - X + \frac{D + L}{2}$

On the left side of column No. 17 $= - X - \frac{D + L}{2}$

As to the influence of wind pressure on columns Nos. 17, 18, 19, 20, the porcedure to find stresses is similar to the one explained for columns Nos. 4, 5, 6; that is, after finding the values of X and Y for each story (X_{16} and Y_{16}, X_{15} and Y_{15}..........X_0 and Y_0) summarize their numerical values, downward, until the basement is reached. For instance, column load for sixteenth story is X_{16} and Y_{16}; fifteenth story is $X_{16} + X_{15}$ and $Y_{16} + Y_{15}$; fourteenth story is $X_{16} + X_{15} + X_{14}$ and $Y_{16} + Y_{15} + Y_{14}$, and so on.

In other words, the overturning moments of the wind are resisted by two couples:

$$X(2W_1 + W_2) \text{ and } Y.W_2$$



Shear Diagram *Fig. 13*

By an inspection of the vertical shear diagram, Fig. 13, it will be noticed that the shear, due to wind loads, is constant from column No. 20 to column No. 19 (— X), again constant from column No. 19 to dolumn No. 18 (— X — Y) and finally constant from column No. 18 to column No. 17 (— X).

The writer believes that the method above illustrated for proportioning girders and columns will be quite useful and safe for all practical purposes, without laying claim to absolute correctness. The more perfect the column connections are, the more reason is there to expect close results. As in any other general rule, there are, of course, special cases that must be treated by themselves, as exceptions. The columns should be anchored by strong rods into or below the foundations, if the graphical lay-out of the wind pres-

sure and dead weight of the building shows that the resultant at level of foundation falls outside the middle third of the base. As to bracing this building in its longitudinal direction, the standard connections between beams and columns are quite sufficient. For the lower part of the building (terminating at the thirteenth floor level) the ratio of length to height is as 1 : 1.64. For the upper front part, terminating at roof over sixteenth story, the ratio of length to height is as 1 to 1.20. Between columns No. 10 and No. 11 is a brick wall, running continuously from second floor to roof, helping to stiffen the building transversely.

5. TYPICAL DETAILS.

The typical details, shown on plans Fig. D, Plate I, and Plate III, have already been mentioned in describing the various classes of work to which they belong. In Fig. D is shown the cantilever girder between columns No. 13 and No. 14; one column (wall column) rests on top of the girder, while the anchor column (No. 14) rests directly on the grillage and the girder is framed into it. Plan No. 13 shows the connection of wind-bracing girders and floor girders to columns, and shows column splice. This floor girder (15-inch beam, 60 pounds) rests on a bracket riveted to column. The beam flange will be riveted to this bracket, and the top flange of the beam will be riveted to an angle shelf, to steady the beam. Plan No. 14 shows some eccentric beam connections. It will be seen from the floor plan that the loads carried into column by the wall girders are rather small, therefore the connections are light.

Very often an eccentric wall load is balanced, or partly balanced, by the intermediate beam loads. For example:

Load transmitted by wall girders $= P$.

Load transmitted by intermediate beam $= P_1$.

Moment of wall girders $= Pd$.

Moment of intermediate beam $= P_1d_1$.

Pd may be equal to, or larger or smaller than, P_1d_1.

Fig. 14 shows such a case. This should be considered when wall columns are proportioned, as the eccentric load may be less than is expected.

Fig. K, Plate III, shows steel construction in bay window framing in front of building, as shown on the general front elevation, Fig. A, Plate I. At the floor level, and attached to front girders by bent plates and a cantilever construction carrying the loads into the floor construction, are channels properly framed to follow the outline of the bay window. A concrete floor will be built in between the channels and the front girders. The framing

is suspended by 3 x 3-inch angles, as indicated; angles being fastened to cantilever construction, as indicated, at fifteenth, twelfth, ninth, sixth and fourth floors.

GENERAL REMARKS.

It is important to write out a specification for the kind of material wanted in the various parts of a steel structure. The special requirements for steel, as to amount of sulphur and phosphorus allowable, and as to tests and inspection of raw and finished material, are decided by each architect or engineer for himself; still there are some general points which should not be overlooked. All beams used in foundations should have three to four coats of paint, raw linseed oil forming the binder, and oxide of iron or red lead the pigment. Before applying paint, the surfaces should be absolutely clean. If hammering and wire brushing will not render them

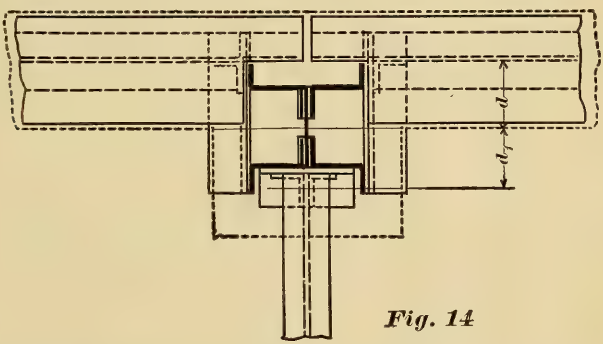


Fig. 14

so, the sand blast should be used. The grillage box girders should be tight, so that no water can get in under any circumstances that might arise. These also ought to have three to four coats of paint. The floor beams should have end connections strong enough to carry the load safely into the girders. In short spans the standard connection angles may not suffice. Where wall girders or other beams connect with columns eccentrically, connections should be so designed as to transfer the load into the entire column, not into part of it only. Where wall girders have cover plates, the rivets should be flattened on top of the cover plate, in order to give better bearing for brick or stone work. Where beams connect to columns with a connection angle above (connecting to top flange), give an allowance of one-eighth to one-quarter inch to allow for irregularities in depth of beam. As to paint, the writer believes that, as long as the body of the paint is good unadulterated linseed oil, it is immaterial whether the pigment is oxide of iron or red lead.

The estimated weight of steel in the building here described is 795 tons, and the estimated cost price for furnishing all steel and erecting it at St. Louis, riveting all connections and giving all steel an extra coat of paint after erection, is $47,000 at prevailing prices, September, 1900. Analyzed, the weight and price appear as follows:

Number of cubic feet in building, using outside dimensions, 745,000.

Weight of structural steel, per cubic foot of building, 2.13 pounds.

Cost price of structural steel, per cubic foot of building, 6.31 cents.

Cost of structural steel, per pound, 2.96 cents.

The writer wishes to express his thanks to Mr. Wm. Frye Scott, architect, New York city, formerly a member of the Engineers' Club of St. Louis, who assisted in getting up the architectural features, arrangement of rooms, stairways, elevators, etc., for the building discussed in this paper.

THE ENGINEERING SOCIETY—ITS RELATIONS TO THE ENGINEER AND TO THE PROFESSION.

Annual Address by H. J. Malochée, President Louisiana Engineering Society.

[Read before the Society, January 12, 1901.*]

By constitutional right your President has the floor on this occasion, and he begs your indulgence if, at any time, he should become tiresome or should say anything that does not meet with your approval or should offend any one by any statement that he may make. He wishes, however, to assure you that the privilege is one that he fully appreciates, and one that has given him no little concern since his elevation to the presidency of your Society, wishing then, and now, as he has always done, to continue in the footsteps of his predecessors and to further at all times the interest of your body and that of the profession. Being sensible of the honor conferred and fully aware of the futility of his own efforts, but for the support given him by the members of the Society and by his associates on the Direction, he wishes to acknowledge with gratitude their assistance on all occasions when the future of the Society was involved, its interests were at stake and its development and advancement under consideration.

A retrospect of the Society's progress during the three years of its existence will, by way of introduction to what I have to say, serve to place before the members of the Society, and before those of the profession who have not honored us with their valued membership, some idea of the good to be derived from such membership, professionally, personally and otherwise.

Beginning with twenty-six charter members, the Society has gradually increased to the comparatively large membership of seventy-five members of all classes. It has increased its furniture and other assets; it has preserved intact its cash balance in bank; it has, through the establishment of a well-furnished library, given to its members free access to books and periodicals worth a hundred-fold their annual dues. Its members have listened to a number of important papers specially prepared for its meetings, the value of which has been fully recognized by every one. A movement of importance was started toward the protection of the public against the imposition of the charlatans in the profession, and it bids fair to be successful in a short time. The social features have not been neglected, and we count in three

*Manuscript received January 17, 1901.—Secretary, Ass'n of Eng. Socs.

years' existence two outings and two smokers of unusual significance and success, the first two being especially so through the delightful and beneficent presence of a large number of ladies.

In view of the great work already done and of the large amount still remaining to be done by this organization, in view of its importance and power for good, would it be amiss to consider the Engineering Society from the theoretical and practical standpoint, to consider its duty to its members, its duty to the profession at large, its ability as a teacher, as a social factor and as a factor in forming public opinion on the value of engineering service?

Throughout the past ages man has sought his kind, has formed associations for his protection and advancement, and, as Montesquieu says, this state of association has in itself developed a state of war, the very reason for this latter state being the recognition of his own superior strength or weakness. Comparisons of the strength or weakness of this or that individual, and the confidence, derived from these comparisons, in one's own strength, made this state of war possible. This state of war has not, however, caused the destruction of the race; it has improved it; it has made of it a living, active body, and the more active this state of war the greater has been the effort to live through it and the greater the results attained. Our civilization, our commerce, our industries, our government, our states, our municipalities, our buildings, our homes, our fight for life, all are combined to make this state of war and to increase the world's efforts toward the goal which it has set for itself,—viz, the happiness of all.

And in this work the engineer stands as the exponent of the highest aims, the leader in some of the most important works, the creator of new methods and processes for the improvement of mankind and its condition, the maker of opportunities never dreamed of, the designer of magnificent monuments and buildings that serve to elevate us and stir us on to the ultimate aim for which we have been created.

But all of this work, all of this designing, all of this execution, all of this leadership,—in fine, all this display of genius,—has not been arrived at without effort, constant and persistent. It has been reached only after studious research and varied experiment of the most serious and assiduous kind, until nature, after opening its great book of laws to the engineer, has, through these very laws, become, together with its materials, his slave for the advancement of the entire race and the personal comfort and benefit of its members.

The engineer has arrived at this very enviable position through a number of causes besides the one of self-preservation mentioned heretofore, but none can be considered of greater importance nor productive of greater results than the technical college and the technical society. It is true that there come into the world some men so vigorous of mind and body, so transcendental in their genius, that they are not in need of the assistance of their fellows; but those men are few and far between, and it must be admitted that the larger proportion owe to education the knowledge with which they are endowed, or the thoughts which emanate from their brains. This is possibly truer of the engineer than of most men, for the engineering knowledge of centuries has been condensed into the knowledge of the present day by constant study of the results attained under the tentative methods that formerly prevailed and by the examination of the various applications of the principles and laws of nature as shown by the works of the great scientists and engineers.

Through the means of the high-class experimental laboratories of the present day, we have peered into the hidden world, into the methods and doings of nature itself, until we have practically discovered all of its great secrets with the exception of the essence of life. But who has preserved all the details of this experimentation? Who has collected the data and the results? Who has verified them? The answer comes quickly and naturally,—the technical college and the engineering society. But they have done more yet, they have conjointly elevated the standard of the profession, improved its ethics and by proper records preserved for all engineers the knowledge, research and investigations of all the engineers of the world.

The great and important duty and work of the technical college in training the youth of this generation in the knowledge necessary for the proper direction of their energies without engaging them in the serious mistakes which must, of necessity, be the result of direction by untrained men. This duty and work need no elucidation, no commendation, no praise from any of us; for the results, the work of its graduates, show for themselves without any words from me. This training is so well recognized as a prerequisite to the acquirements necessary to one who wishes to enter the field of engineering that some of the large machine shops do not take in any other apprentices than young men who have graduated from technical schools of recognized standing, and the requirements for membership in either the American Society of Civil Engineers or the American Society of Mechanical Engineers almost demand such education or its equivalent.

Has the technical society done its part of the work? Emphatically, yes. The young engineer leaving college has only been taught correct principles, and informed upon the methods which have been found most successful. But his technical education has fitted him for the battle of life, and particularly for the post-graduate work which he needs in order to keep abreast of the times. It has placed him in a position wherein he can, through correctly directed judgment, discern between right and wrong, technically speaking as well as professionally, and I ask, what are the means at hand for this advanced work, for the study of ever-changing conditions and applications?

Such means are found in the experience acquired by each individual, in the experiences of others, as published in the technical press, in the valuable bulletins and catalogues issued by manufacturing companies, and in the papers presented before the various technical societies of the world. But, by reason of man's tendency toward association, by reason of local interest, of personal acquaintance derived from such association, of the light acquired by discussion between individuals, by reason of the social features attached to such organizations, the Engineering Society is the most attractive of these means of improvement, and we find it increasing in its membership, in the value of the papers presented, in the advantages it offers and in the fraternal feeling it engenders between the various members of the profession.

Considered from the theoretical standpoint, such a society as ours is a rendezvous or meeting place for its members, for an exchange of views, for the discussion of experiences, for the collection of a library and for the presentation of new ideas and their discussion, for a more intimate personal acquaintance, for the consideration of questions of ethics and other matters of interest to its members, for the recognition of services rendered to the profession at large, for the instruction of the world in the ideals which the profession has set for itself, for the exposition of the benefits to be derived from the raising of these ideals and for the education of the younger by the older members,—in fact, the aim of the Society is the general advancement of its members and of the profession at large. Practically speaking, what does such a society as ours bring forth? It gives us all of the above advantages in a greater or lesser degree. The eminent engineer learns to know the younger member from a different point of view than in the light of an assistant; the chief learns of the hidden ability in the more timid employe; the assistant has the opportunity of placing himself properly, possibly in a prominent

way, before the head of his department by correct discussion of matters presented to the Society; the plane of equality upon which they meet opens the door for a more thorough understanding of their dispositions and characters, and the chaff is unconsciously separated, or at least distinguished, from the wheat. The sensible increase of a library, and the improvement in its cataloguing and therefore in its value, and the emulation derived from the consideration of the work done by the other members, form not the lesser advantages to be gained from such association. All these things we have, but we must not stop here. A larger number of members should take active part in the proceedings; the membership should be increased so as to include every member of the profession deserving such membership; the ethics of the profession should be zealously guarded, and, if possible, their standard heightened; the certificate of membership in this Society, although to-day a recognized guarantee of ability and integrity, should become a passport into the most carefully guarded and exclusive places in the world, and the voice of authority should be that of its members.

The Engineering Society owes it to its members to take up and study all subjects of engineering interest that may come up in the natural course of events. It should express itself against all methods that tend to affect injuriously the standard of the profession, and should, without fear or favor, condemn those who, through their conduct, tend to lower that standard. The value of the services rendered by professional engineers should be recognized to be as great as, if not greater than, that of any of the other learned professions, and it behooves the Engineering Society to discredit the men or man who would have us give an opinion for a mere pittance or design some great work for a mere living salary. It owes it to its members to investigate carefully the professional, business and social standing of the men who knock at its doors for admission, for surely integrity, honesty, and conscientious devotion to duty and truth are the necessary attributes of an engineer as well as the qualifications necessary to a gentleman.

In the light of our experience during the latter part of the nineteenth century, in the light of the increased importance of the engineer in our daily life and of the position assumed by him with relation to our industrial life, how can we expect his influence to be *nil* during the next century? For my part, I cannot see in what sphere of action this influence will not be felt. It is now felt throughout the world. There exists to-day neither time nor

distance on this earth. The telephone, the telegraph; the railroad, the steamship; the street car, the automobile; the merchant ship, the battle ship; the magazine rifle, the 100-ton breach-loading gun; the silk dress, the cotton goods; the blast furnace, the cotton mill; the necessaries of life, its luxuries,—all these things, and more, owe their existence to the engineer and to his genius of design and application. Can this influence be diminished? The engine of twenty years ago was of 300 H. P.; the engine of to-day is of 5000 H. P. The steamship of a few years ago was a 1200-ton ship; the steamship of to-day is a "Deutschland" or an "Oceanic," with 16,000 tons carrying capacity and 33,000 H. P. of driving machinery. There must and can be no stop in the world's progress. The engineer, as the leader in this march toward the goal of universal happiness, must forever and with vigilance watch the opportunities for advancement and improvement. Sanitary and health conditions must be looked into, so as to lengthen the life of the human race; the cost of the poor man's loaf and of his cotton and woolen goods must be decreased, the productiveness of his labor must be increased; and to the engineer we shall turn as the benefactor of mankind, the promoter of its happiness, the user of the resources of the world, the creator of its opportunities, the framer of its most important destinies.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

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A STUDY IN HYDRAULICS.

BY GEORGE H. FENKELL, MEMBER DETROIT ENGINEERING SOCIETY.

[Read before the Society, May 18, 1900.*]

THE student in hydraulics at first is often led to believe that the formulas for the flow of water through channels of different kinds, through orifices and over weirs, are derived from certain well-known laws, such as those of gravity and friction, whose character and nature have been so thoroughly studied that they admit of little or no variation. His belief in that line is strengthened when he finds how long many of these formulas have been in general use and the number of years they have appeared in precisely the same form in text-books and manuals.

If the subject is pursued farther, however, it will be observed that all have been founded upon, or at least verified by experiments made at different times, by different persons and under various conditions. Many have evolved formulas from their own results, and perhaps a limited number of others that agree with their own fairly well, disregarding those made under as favorable conditions, but which do not seem to follow the same laws.

A large number of formulas have been derived to determine the friction in closed pipes or conduits running full, under pressure, such as cast iron, wrought iron, steel and wood; and so often, in fact, has this ground been beaten over that many, after various attempts to find rules that will fit all cases, have given

*Manuscript received March 14, 1901.—Secretary, Ass'n of Eng. Socs.

up in despair and gone back to some simple equation, believing, with Hamilton Smith, Jr. ("Hydraulics," page 200), that "It is very doubtful whether one general expression with constant co-efficients can be framed, which will, with a fair degree of accuracy, give the value of $v - r, s,$ and the conditions of the wetted surface being known."

It seems probable that, if all the experiments that have been published to the present time had been made with only that allowable amount of error which even the most careful cannot avoid, many of the peculiarities entering into the different formulas would be missing, and that one set of experiments would tend to check another. From the time when Couplet, who was one of the first to recognize the value of accuracy, published the result of his work at Versailles in 1732 ("Récherches sur le Mouvement des Eaux"), down to within a few years ago, very little attempt was made to separate those experiments which had been made with skill and care from those which were but approximations or were the result of careless and indifferent work.

In 1885, Hamilton Smith, Jr., member of the American Society of Civil Engineers, published his "Hydraulics," and in it, for the first time, so far as the author can ascertain, an endeavor was made, by plotting v with c (Chezy formula, $V = c\sqrt{rs}$) on squared paper, to pick out those experiments which, by the smoothness of the curve thus obtained, showed accurate and careful work. The result of his investigations led him to believe that the co-efficient c increased in some unknown relation to the velocity, although above one foot per second the increase in c was very slight.

During the past few years several sets of experiments have been made on large pipes of various kinds, and it is the intention of the author to discuss the published results obtained from these, as well as most of those reviewed by Mr. Smith.

In the discussion on "Experiments on the Flow of Water in the Six-Foot Steel and Wood Pipes," etc., by Marx, Wing and Hoskins (Transactions of the American Society of Civil Engineers, Vol. XLIV, December, 1900), the author made some comments on the flow of water in large riveted pipes, and Plates Nos. 7, 8 and 9 of this paper were there presented.

As $V^2 = 2gh$, $h = \frac{V^2}{2g} = H_v =$ velocity head. (The author has used 64.4 as the value of $2g$.) If the loss of head or friction (H_f) varies as the square of the velocity, and the velocity head (H_v) be plotted with the loss of head (Hf) on squared paper, a

straight line through the origin will be the result.* If the line so obtained is not straight, the observed loss of head does not vary as the square of the observed velocity.

In this discussion, the average straight line through a number of points is found by first obtaining the center of gravity of all the points, by dividing first the sum of the ordinates and then the sum of the abscissas by the number of observations. The centers of gravity of these points on either side of this center are then found, and, as these three points lies in a straight line, they determine the average line as given on the plates and in the table. It may be that the method of least squares would have been preferable, as the probable error could have thus been obtained. The method used, however, involves less labor than the former and is much more satisfactory than averaging with a fine thread.

For some time past, many engineers, including those engaged in hydraulic work, have employed some method of plotting to obtain co-efficients or exponents. Dr. Osborne Reynolds presented a paper, "An Experimental Investigation of the Circumstances which Determine whether the Motion of Water shall be Direct or Sinuous, and of the Law of Resistance in Parallel Channels," before the Royal Society of London, March 15, 1883 (Proceedings Royal Society of London, Vol. XXXV, page 84), in which, by plotting the logarithms of the resistances per unit length as abscissas and those of the velocities as ordinates, a straight line results, *provided* the velocity varies directly as some power of the friction. The slope of the line found gives the values of the exponent. Professor Edwin C. Pickering, Director of Harvard College Observatory, has for many years plotted by means of logarithms, and in 1893 John R. Freeman, M. Am. Soc. C. E., Member of the Boston Society of Civil Engineers, prepared lithographed sheets drawn to a logarithmic scale on both abscissas and ordinates, which admit of a wide use, and have been extensively used by Mr. Freeman and others in experiments on flow of water.†

*The most satisfactory way of converting velocities into velocity heads is by means of diagrams made on sheets of cross-section paper about 16 x 20 inches. Plot enough points from a table to give an accurate curve, and if necessary increase the scale for low velocities. When more convenient the square of the velocity may be used instead of the velocity head.

†These sheets are 20 x 20 inches, ruled both to a 10-inch and a 20-inch base, and the scale and print are remarkably good. The author is indebted to Mr. Freeman for several sheets.

Rudolph Hering, M. Am. Soc. C. E., Member of the Boston Society of Civil Engineers (Transactions American Society of Civil Engineers, 1879), published several diagrams in a paper, "The Flow of Water in Small Channels, after Ganguillet & Kutter," etc., and similar diagrams were published by Arthur N. Talbot, Member of the American Society of Civil Engineers (*Engineering News,* August 11, 1892), in an article, "Diagrams for Flow in Pipe Sewers," and by F. S. Bailey, in "Diagram for Discharge of Two- to Seven-Foot Brick Conduits Flowing Full" (*Engineering News,* November 15, 1894), in which the velocity or quantity is plotted at an arithmetic scale on the ordinate and the grade or slope at a logarithmic scale on the abscissa, the different sizes being represented by a diagonal line.*

In Diagrams "A" and "B" in the "Graphical Solution of Hydraulic Problems" (New York, 1897), Freeman C. Coffin, M. Am. Soc. C. E., Member of the Boston Society of Civil Engineers, employs logarithmic ruled paper to determine graphically the increased friction in old pipes over that in new ones.

The advantages in using logarithmic ruled paper are many, especially for the purpose of obtaining fractional exponents, and diagrams that could otherwise be represented only by curves of a complicated nature are much simplified; but for the case at hand, to study graphically the relation existing between velocity and friction in closed pipes, and especially the initial error in the observations or reductions, if such exist, the author believes the method adopted in this paper to be at least as simple and, owing to uniformity of scale, more easily comprehended by inspection than any other yet published. It was first suggested in 1897 by Gardner S. Williams, M. Am. Soc. C. E., Member of the Detroit Engineering Society, and used quite extensively by him and by Mr. C. W. Hubbell, Assoc. M. Am. Soc. C. E., Member of the Detroit Engineering Society, and the author in reducing experiments on frictional loss in curves of different radii in large cast iron pipe.

It is very difficult to obtain a series of experiments on as complicated a subject as the flow of water through pipes without some errors entering into the results; but many of these errors, under ordinary conditions, such as air in gage connections, calibration of instruments and leaks in instruments and connections, are nearly constant for all velocities; while others, such as personal error of observers, tend to balance each other. As nearly

*Since presenting this paper, a somewhat similar diagram appeared in an article "Diagram Giving Discharge of Pipes by Kutter's Formula," by John H. Gregory, Jun. Am. Soc. C. E. (*Eng. Record,* Nov. 3, 1900).

all experimental results include some of these errors, it is hardly to be expected that, even if H_f varies as the square of the velocity, the resulting line will pass *exactly* through the origin. The equation will, therefore, become $H_f = aH_v \pm b$, in which $\pm b$ is a constant for each set of experiments and indicates the distance from the origin at which the line cuts the H_f axis. If we move this line, parallel with itself, until it passes through the origin, it will then represent the relation existing between H_v and H_f.

There are many things that may affect the final results obtained to such an extent that when H_v and H_f are plotted together some kind of a curve will result, and it is evident that, when such is the case, it is impossible to transform them into a straight line. It seems possible that peculiarities of this kind may have been sometimes caused either by the effect of curvature in the line of pipe experimented upon or by errors made in determining q, v or H_f. Many of these experiments were gaged by means of weirs or orifices, and, judging from the discussion in various articles which have recently appeared, it seems possible that co-efficients were used which may have been in error several per cent. In the following plates, points which do not plot straight are connected with a broken line.

In this paper the author has deduced the values of c in the Chezy formula. If the relation between H_v and H_f can be represented by a straight line passing through the origin, $H_v \propto H_f \propto s$. If $v = c\sqrt{rs}$, $c = \sqrt{rs}$. As $v^2 \infty H_f$, and as r is constant for each size of pipe, c will remain the same for all velocities in the same pipe. This constancy of c holds good in any formula of the form $v = cr^x s^y$ provided $y = 2$.

On the following plates, all the experiments which the author has been able to plot in this way are shown at various scales. Many experiments, however, which have been conducted with great care are omitted in this discussion because there is not enough range in the velocities used, to determine accurately the locus of H_f and H_v. It is also necessary that this range in velocities should be made on the same section of pipe, covering as short a period of time as possible, as the various effects of curvature in different lines, and the ever-changing conditions of interior surface, may cause considerable variations. Many of the experiments made by Clemens Herschel, M. Am. Soc. C. E., on the riveted pipes of the East Jersey Water Company ("115 Experiments" by Clemens Herschel) are omitted here for this reason. It may be that some experiments that should have been

included have been entirely overlooked by the author. It is believed, however, that no serious omissions have been made.

Table I, accompanying the following plates, is self-explanatory. The equation of the average straight line, as shown on the plates, is:

$$H_f = aH_v \pm b,$$

and, when moved parallel with itself until it passes through the origin, it becomes:

$$H_f = aH_v.$$

Multiplying the velocity head, of any velocity, by a, the product is the loss of head per 1000 feet of pipe. Column 14 contains a, and Column 15 contains b in the foregoing equations. Column 16 contains c, as figured from H_f. As explained before, c is constant for all velocities. It is not the intention of this paper to advance the formula just mentioned as one to be used in every-day practice for estimating friction, discharge, etc., as the range in the values of a entirely unfits it for such a purpose. Neither is it the author's intention to cast discredit on any set of experiments. As the name of this paper indicates, it has been the author's aim to throw more light on this important subject in hydraulics by a systematic study of previous experiments. It has been claimed that the *ideal* formula is $v = cr^x s^y$, in which x and y have such values that c will be independent of the size of pipe and of different slopes of the same pipe. This can be possible only if y remains constant for all sizes of pipes.

The question has often been discussed, whether the friction varies as the square of the velocity, and many attempts have been made to prove or disprove this proposition. The author will not attempt to analyze any of these discussionss, but will mention a few of the most recent papers which have attempted to solve this problem.

1. In a very interesting paper by William E. Foss, member of the Boston Society of Civil Engineers, "New Formulas for Calculating the Flow of Water in Pipes and Channels" (JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, June, 1894), from the line obtained by plotting the logarithm of v with the logarithm of s (see Plates 1 and 2 of that paper) on squared paper, it is found that $v^{\frac{11}{6}} \propto s$.

2. Desmond FitzGerald, M. Am. Soc. C. E., Member of the Boston Society of Civil Engineers, deduced from the results of his experiments on the 48-inch cast iron Rosemary pipes ("Flow of

Water in Forty-eight-Inch Pipes," Transactions American Society of Civil Engineers, Vol. XXXV, 1896) that

$$v \propto s^{\frac{1}{2.02}} \text{ when tuberculated, and}$$

$$v \propto s^{\frac{1}{1.91}} \text{ after being cleaned.}$$

Plate 6 shows these experiments, together with those made on the same pipe by F. P. Stearns, M. Am. Soc. C. E., when new in 1885. These two series were conducted with great care and are among the best that have ever been published. It will be observed, from Mr. FitzGerald's results, that $v^2 \propto H_f$ very nearly, and even if plotted to a much larger scale than shown in Plate 6, it will be seen that the point falls in a straight line with remarkable precision.

3. In "The Flow of Water in Pipes," by C. H. Tutton, member of the Engineering Society of Western New York (JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, October, 1899), by the use of logarithms, plotting on squared paper, he finds that if $v = cr^{66}s^{51}$, c will remain constant; that is, that $v \propto s^{51}$.

4. Mr. M. E. Sullivan ("New Hydraulics," Denver, 1900) assumes, as one of the laws of friction as applied to a liquid in contact with a solid: "The friction on any given unit of surface will increase as the square of the velocity." An attempt is made to prove by theory, and to substantiate by a limited number of pipe experiments, that, if $v = c\sqrt[4]{r^3}\sqrt{s}$, c will remain constant.

All of these papers and discussions make the assumption that, in all experiments, the curve representing the relation between friction and velocity, if plotted from the actual observation, will pass through the origin. The author believes this assumption to be generally somewhat in error. As has been explained before, if a series of observations, as plotted on the following plates, fall in a straight line passing through the origin, $v^2 \propto H_f$: If the following plates are carefully examined, it will be found that most of the best experiments on large pipes plot straight, although none pass exactly through the origin. There are exceptions, however, in the smaller sizes.

Plate 19 shows experiments on two kinds of mill hose, by John R. Freeman, M. Am. Soc. C. E. (Transactions of the American Society of Civil Engineers, Vol. XXI). Their accuracy is beyond question, but the line of their points is slightly curved.

Although most of the experiments on large pipe plot straight, it will be observed that many, made on smaller pipes, are more or less curved (many of these were made by Mr. Darcy; see Plates 3, 5, 11, 13, 14 and 18), and some of those which the author has

reduced to straight lines show a slight arc. This indicates that H_f does not vary as v^2. In several sets, a line passing through the observations forms a sine curve, which appears much plainer if plotted to a larger scale. (See Plate 5, No. 11; Plate 7, Nos. 19, 20 and 21; Plate 8, No. 23; Plate 11, No. 30; Plate 12, No. 29; Plate 13, Nos. 35 and 37; Plate 16, No. 40, and Plate 17, Nos. 44 and 45.) These have all been averaged straight, as the variation is so slight. It must be admitted, however, that whether straight, as the larger pipes show, or slightly curved, as a few of unquestionable accuracy plot, they should pass through the origin; for, if there is no velocity, there should be no friction. In other words, if v and H_f are plotted on cross-section paper, a curve is the result. If it does not pass through the origin it should be moved in some way until it does; or, if H_v is plotted with H_f, as shown on the accompanying plates, the line, whether straight or curved, passing through these points must pass through the origin if we eliminate what error we can. If a straight line will represent an average of the points, the constant in its equation should be eliminated, thus making c (in Chezy formula or any other formula of the form $v = cr^x s^y$, in which $y = 2$) constant for all velocities; or, if slightly curved, this curve should be moved until it passes through the origin, whence c will vary slightly with different velocities, although much less than has generally been computed. When co-efficients in any formula for the friction in pipes are obtained for each observation, they will generally be found to be of much less practical value than when the entire set is taken as a whole, and when one co-efficient is deduced, representing, as nearly as may be determined, a general average after making all possible corrections.

All values of a ($H_f = aH_v \pm b$), and c ($v = c\sqrt{rs}$), as published in the table, are shown graphically on Plate 21, and, if examined carefully in connection with the other plates, many peculiar variations will be noted which can hardly be accounted for by reasons ordinarily advanced.

The following are a few velocities, with their respective velocity heads, which may aid in understanding the plates:

Velocity in Feet per Second (v).	Velocity Head in Feet (H_v).
0.5	0.0039
1.0	0.0155
1.5	0.0349
2.0	0.0621
2.5	0.0970
3.0	0.1398
4.0	0.2485
5.0	0.3882
6.0	0.5590
7.0	0.7609
8.0	0.9938

PLATE 1

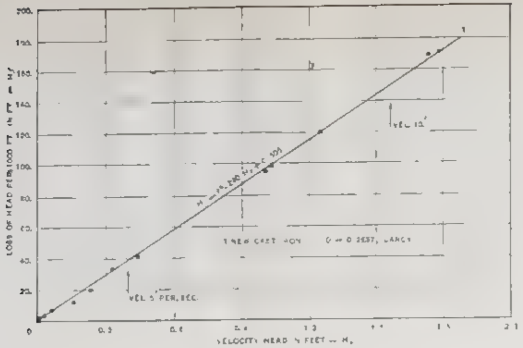


PLATE 2

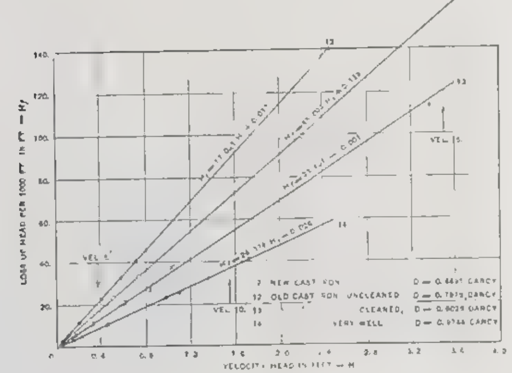


PLATE 3

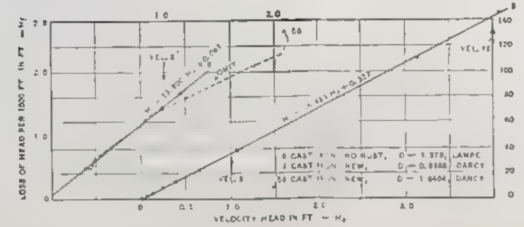


PLATE 4

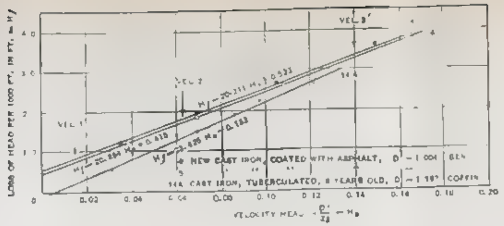


PLATE 5

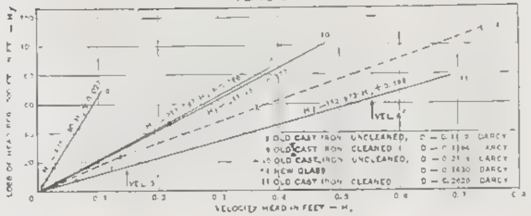


PLATE 6

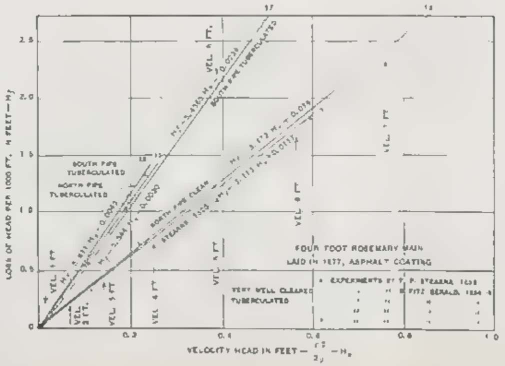


PLATE 7

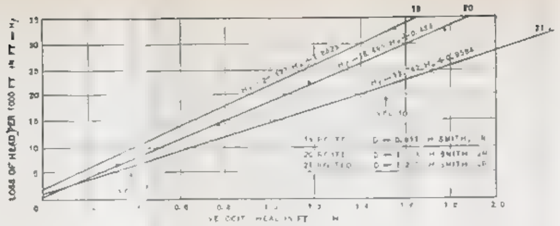


PLATE 8

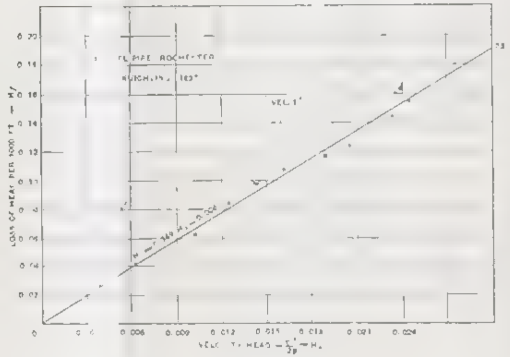


PLATE 9

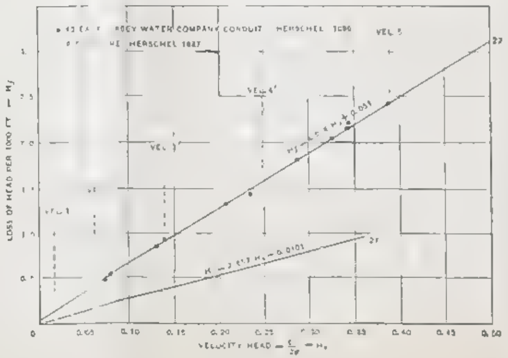


PLATE 10

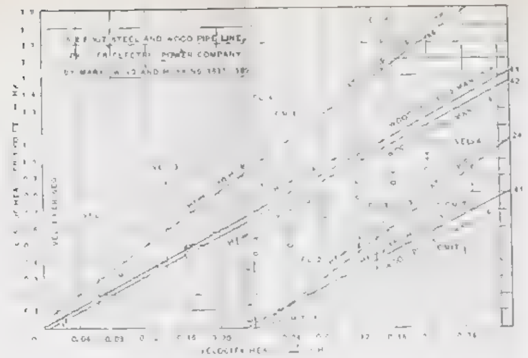


PLATE 11

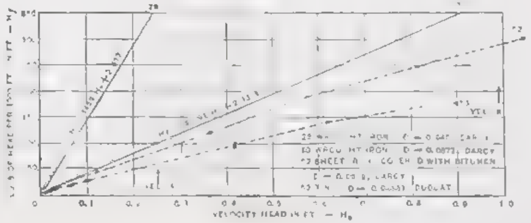


PLATE 12

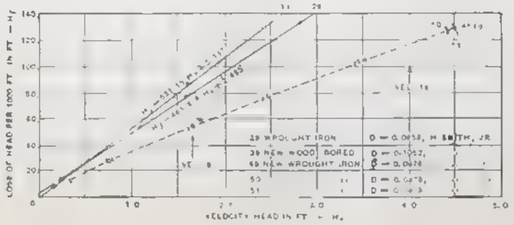


TABLE No. 1.

TABLE OF PIPE EXPERIMENTS COLLECTED AND TABULATED BY GEO. H. FENKELL, 1900.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Plate No.	Series No. in Plate	Observation Nos. as Pub'd.	Where Found.	Author	Made by	Date.	Range of Velocities	Velocities Measured by	Pipe			No. of Observations	$H_f = aH_v + b$		$v = c\sqrt{rs}$	Pub'd Values of C $v = c\sqrt{rs}$.		Condition
									Kind	Diam	Length.		Value of a	Value of b.	Value of c.	Lowest.	Highest	
1	1	206-218	Hydraulics	H. Smith, Jr	Darcy	1849-51	0.3-10 7	Tank	Cast Iron.	0.2687	366.1	13	95 290	+ 0 305	100 3	75 1	100 5	New
2	2	219-228	"	"	"	......	0.5-15.4	"	"	0.4495	365 7	10	45 003	+ 0 139	112 8	94 1	113 5	"
3	3	229-137	"	"	"		0 7-16 2	"	"	0.6168	365.4	9	35 493	+ 0 357	108 5	99 3	109 0	"
4	4	271-274	"	"	Iben	1874-9	1 6- 3 1	"	"	1.004	17684 0	4	20 694	+ 0.415	110 6	90 1	106 5	Coated with asphaltum.
4	5	271-274	"	"	"	"	1 6- 3 1	"	"	1 004	17684 0	4	20 211	+ 0 523	112 5	89 3	102 7	" " "
3	6	275-278	"	"	Lampe	1870	1 6- 3 1	Reservoir	"	1 373	{25,444 to 31,719 0}	4	13.900	+ 0 061	116 5	110 5	119 4	Smooth varnish
6	7	282-285	"	"	Stearns.	1885	2 6- 6.2	Weir	"	4.000	1747.2	4	3,113	+ 0 212	143 8	140.1	146 7	Coated with asphaltum.
5	8	179-185	"	"	Darcy.	1849-51	0.2- 2 1	Tank	"	0 1179	374 9	7	625.390	+ 0.027	59.1	58.1	61 7	Old, uncleaned
5	9	186-192	"	"	"	"	0 4 3 7	"	"	0 1194	374 9	7	217 597	+ 0 766	99 5	80 5	99 1	" the above cleaned.
5	10	193-198	"	"	"	"	0.4- 3 7	"	"	0 2608	366 3	6	211 897	— 0 177	68 3	62 0	68 9	" uncleaned.
5	11	199-205	"	"	"	"	0 6- 5 0		"	0 2628	366.3	7	112 973	+ 0 366	93 2	85 2	93 2	" the above cleaned
2	12	238-245	"	"	"	"	1 0-12 6	"	"	0 7979	365 3	8	57 021	+ 0 017	75 3	73 6	75 8	" uncleaned.
2	13	246-253	"	"	"	"	0 9-14 7	"	"	0 8028	365 3	8	33 601	— 0 001	97.7	80 3	95 1	" cleaned
2	14	254-261	"	"	"	"	0.8-10 4	"	"	0 9744	365 3	8	24 376	— 0.026	104 1	90 9	105 5	" very well cleaned
4	14a	1-7	Graf. Sol of Hyd. Problems, Coffin.		F C Coffin	.	0.8- 2 8		"	1 167	12,700	7	23.425	— 0.133	97.1	98 6	136 3	8 years old, tuberculated.
6	15	I-XXI	Trans. Am Soc C. E., 1896	Fitsgerald.	Fitsgerald	1894-5	0.3 3 5	Weir	"	4.00	1615 7	21	5 544	— 0 004	107 8	88 0	114 8	Old, tuberculated
6	16	XXII-XXIX	"	"	"		0 4 3 5	"	"	"	1615 7	8	5 911	— 0 004	104.4	101 2	107 1	" "
6	17	LI-LVI	"	"	"	.	3 7- 5 9	"	"	"	1615 7	6	5 457	— 0 023	108 6	108 4	109 8	" "
6	18	XXX-L	"	"	"	"	0 4- 7 2	"	"	"	1615 7	21	3 172	0 002	142 5	116 5	143 6	Very well cleaned
7	19	340-344	Hydraulics.	H Smith, Jr	H. Smith, Jr	1877	1 7-10 0	"	Riveted.	0 911	{684 8 to 730 6}	5	20 177	+ 1.8629	115 4	107.1	115 5	Quite smooth.
7	20	345-348	"	"	"	.	4 6-10 1	"	"	1 056	{684 9 to 718 4}	4	18.495	+ 0 458	122 8	109 4	114 4	" "
7	21	349-354	"	"	"	"	4 4-12 1	"	"	1 230	{684 4 to 719 9}	6	13 742	+ 0 9584	123 5	116 6	121 5	" "
9	22	259-270	115 Experiments.	Herschel.	Herschel.	1896	2 1- 5 2	Venturi	"	3 50	81139.0	11	6 076	+ 0 051	110 1	..	..	New
8	23	.	Rochester Am Ros., 1897	....	Kuichling.	1897	0 5 1 2	Reservoir	"	3 167	46339.0	10	6 349	— 0 006	113.2	109 1	116 6	
10	25		Trans Am Soc C E., 1897	Marx Wing & Hoskins	Marx Wing & Hoskins.	1897	0 5 3 8	Venturi	"	6 02	{4367. to 4427.}	29	3 869	— 0 0079	105 5	68	137	"
10	26		Trans Am Soc. C. E 1899	"	"	1899	0 7- 5 1	"	"	6 02	{4367 to 4427}	39	3 850	+ 0 0358	105 6	73 4	1 3 3	2 years old
9	27	.. ..	115 Experiments.	Herschel.	Herschel.	1887	0 5- 4 5	"	"	8 58	152.88	40	2 657	— 0 0101	106.1	105 6	126 5	New
11	28	65-77	Hydraulics	H. Smith, Jr	Darcy.	1849-51	0 1- 3 9	Tank.	Wrt. Iron.	0 0400	374 6	13	1459 66	+ 2 667	66 4	38 7	69 6	New drawn
11	30	78-90	"	"	"	"	0 3- 7 2	"	"	0 0873	372.2	13	330 91	+ 2.1316	88 1	70 7	88 5	" "
14	32	95-100	"	"	"	"	0 2 8 5	.	"	0 1296	371 9	12	108 786	+ 1 846	100 0	72 6	100 3	" "
14	33	143-154	"	"	"	"	0 3-12 8	.	"	0 2710	365 1	12	60 504	— 2 501	125 0	70 7	124 3	New, coated with asphaltum.
14	34	155-165	"	"	"	.	0 6-10 7	"	.	0 6430	305.3	11	23 144	+ 0.765	131 7	103 8	141 0	" " "
15	31	305-308	"	"	H Smith, Jr.	1877	2 3- 6 9		"	0 0576	1668 5	4	306 638	+ 7 411	97 9	88 0	96 8	Partly coated with asphaltum.
12	29	309-315	"	"	"	"	0 9- 4 3		"	0.0853	60,247	7	463 816	+ 2.465	80 6	71 2	86 1	Part old, part new
15	36	7-18	"	"	Bossut	1771	1 1- 4 3	Tank	Tin.	0 1184	{31 97 to 191 84}	12	189 290	+ 1 119	107 0	58 2	108 8	Tin, straight
15	38	19-30	"	"	"	"	1 5- 5 2	.	"	0 1785	"	12	126 772	+ 1 1754	106 7	91 6	114 9	" "
13	35	117-123	"	"	Darcy	1849-51	0 2- 5 5	"	Lead.	0.0586	172 4	7	301 417	+ 2 204	98 3	68 3	97 8	Lead, new
13	37	124-130	"	"	"	.	0.4- 7.6	"	"	0.1345	172 4	7	177 606	+ 2 170	103 9	75 0	103 5	" "
12	39	335-339	"	"	H Smith, Jr	1877	1 7- 4 0	Orifice	Wood.	0 1052	62 05	5	531.15	+ 0 337	68 0	66 5	67 9	New, wood-bored
17	46	375-382	"	"	Darcy&Bazin	1855-8	1 7- 6 4	Tank	"	Rectangular.	103.68	8	10 556	+ 0 017	110 0	107 0	110 3	2,625 x 1 64 wooden pipe
17	47	375-382	"	"	"	"	1.7- 9 4	"	"	"	195 00	8	9 654	+ 0 009	114 8	112 0	115 5	" " "
17	44	383-390	"	"	"	"	1 2- 5 3	.	"	"	49.21	8	21.239	— 0 0657	100.1	96 8	103 2	1 575 x 0 984 " "
17	45	383-390	"	"	"	"	1 2- 5 3		"	"	98 00	8	21 665	— 0 0868	99 1	98 1	102 8	" " "
16	40	....	Water-Supply. Eng	Fanning	Fanning	1880	0 9 4 0		Iron.	1.6667	8171 0	12	12 454	+ 0 017	111 4	97 4	113 5	Wrought iron; cement lined
10	41		Trans Am Soc. C. E., 1897.	Marx Wing & Hoskins	Marx Wing & Hoskins	1897	0 5 3.6	Venturi	Stave.	6 03	2710 0	22	2.657	— 0.0313	127 3	60	131	Stave-pipe, new.
10	42	....	1899	"	"	1899	1 2- 4 9	"	"	"	"	28	2.803	— 0 0188	124 5	...	...	" 2 years old.
10	43	....	"	"	"	"	1 2- 5 3	"	"	"	22672 0	48	2 834	+ 0.0079	123 2	117 3	123 3	" 2 "
20	50	1-10	Trans. Am. Soc C E., 1893.	Benzenberg	Benzenberg	1888	3 9- 7 0	Color (Eosine)	Brick	{12 0 Circular}	2534.0	10	1 4916	— 0 049	120 0	122 7	137 .	New; common brick, good joints
11	53	36-52	Hydraulics	H Smith Jr	Dubuat	1786	0 1- 7.5	...	Tin	0 0881	{65 46 12.301}	17	......	......	......	67 6	119 8	Tin pipe
13	48	110-116	"	"	Darcy.	1849-51	0.1- 4 2	Tank	Lead	0 0459	172.0	7	......	......	......	48 4	98 3	Lead pipe.
11	52	131-142	"	.	"	1849-51	0 1- 8 2	"	S. Iron.	0 0879	371 8	12	......	......	......	44 8	100 1	Sheet-iron, coated with bitumen.
18	57	166-172	"	.	"	"	1.3-10 5	"		0 935	365.5	7	......	......	......	101 3	129 0	" "
5	54	173-178	"	.	"	"	0 5- 6 9	"	Glass	0.1630	147.2	6	......	......	......	80 3	102 4	New, glass
3	58	262-270	"	.	"	"	1 4- 3 7	"	Cast Iron.	1 6404	365.3	9	......	......	......	99 4	110 0	" cast iron.
12	50	287-293	"	.	H Smith, Jr	1887	1.0- 5 3	Orifice	Wrt Iron.	0.0878	60,172 0	7	......	......	......	74 7	100 9	" wrought iron
12	51	294-300	"	"	"	"	1 1- 5.4	"	"	0 0878	60,247 0	7	......	......	......	80.1	100 8	" " "
12	49	301-304	"	"	"	"	2 2 5 4	"	"	0 0876	60,264 0	4	......	......	......	91 6	101 9	" "
19	55	... .	Trans Am Soc C. E Vol 21	Freeman	Freeman.	1889	3 5-19 0	Tank.	Hose	0 211	....	8	......	......	......	...	..	Rubber-lined mill-hose
10	56	....	"	"	"	"	3 5-20 0	"	"	0.217	....	7	......	......	......	...	.	Ordinary unlined linen hose

PLATE 13

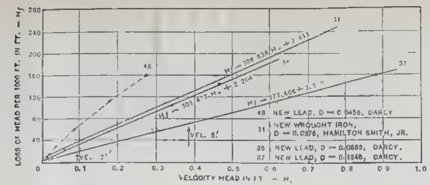


PLATE 14

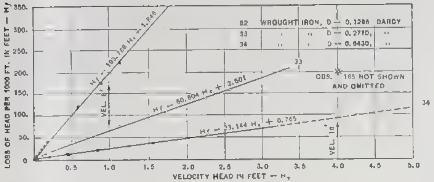


PLATE 15

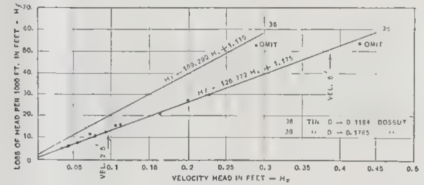


PLATE 16

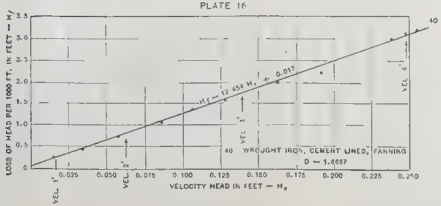


PLATE 17

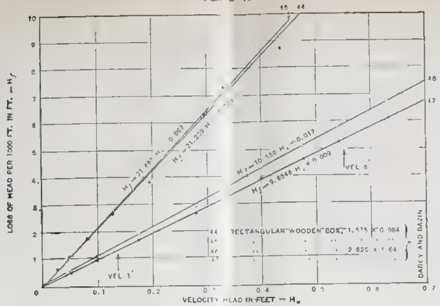


PLATE 18

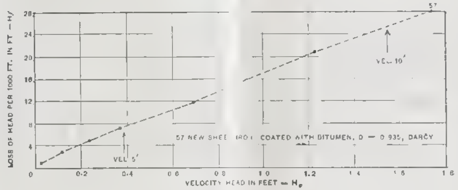


PLATE 19

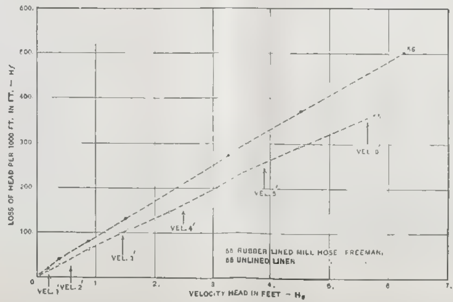


PLATE 20

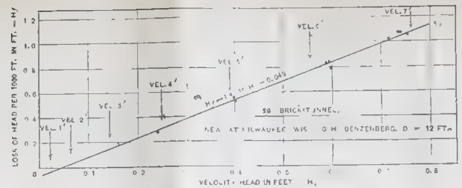
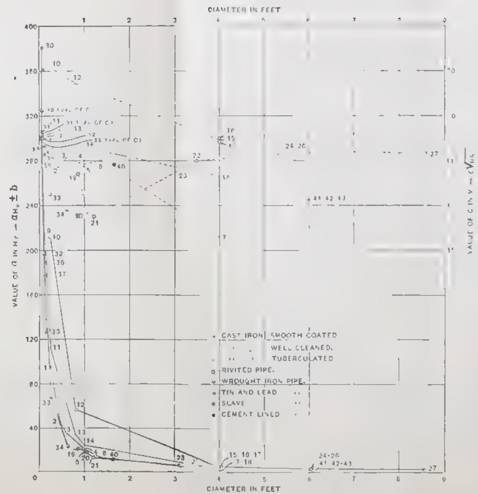


PLATE 21



DISCUSSION.

Mr. Allen Hazen.—The paper of Mr. Fenkell takes up some very interesting problems of the flow of water in pipes. The method of plotting the velocity heads with the friction heads is most interesting. The observation that the points so plotted are generally in a straight line, and the supposition that the distance which this line passes from the origin represents constant error and can be eliminated by drawing another line parallel to it and through the origin, is very interesting and undoubtedly correct in some cases.

The question of the revision of the formula of the flow of water in pipes is always interesting. If we take the general formula $V = CR^x S^y$, suggested by Tutton in the Journal of the Association of Engineering Societies, Vol. XIII, page 151, it will be agreed by every one that the value of C is not constant, but must vary according to the condition of the surface of the pipe and other circumstances; but perhaps the variation depends more upon the accuracy with which the values of x and y are taken than upon any other conditions. If correct values of x and y are taken, C will vary but little for a given condition of interior surface, while with values of x and y far from the truth the variations in C will be greater and more difficult of analysis.

In the Chezy formula x and y are each taken as 0.50. This value for y appears approximately correct. For x it is certainly too low, for the value of C increases with the value of R with considerable regularity. In Kutter's formula for determining the value of C in the Chezy formula, C is made to increase with R, and to such an extent that, for ordinary pipe sizes, and with other conditions remaining the same, V varies nearly as $R^{0.75}$. In Sullivan's formula, which is mentioned by Mr. Fenkell, x is taken as 0.75. As a matter of fact, I believe that 0.75 is nearly as much too large as 0.50 is too small. Tutton, as a result of a discussion of old data by a new and very interesting mathematical method, found, for iron pipe, $x = 0.66$.

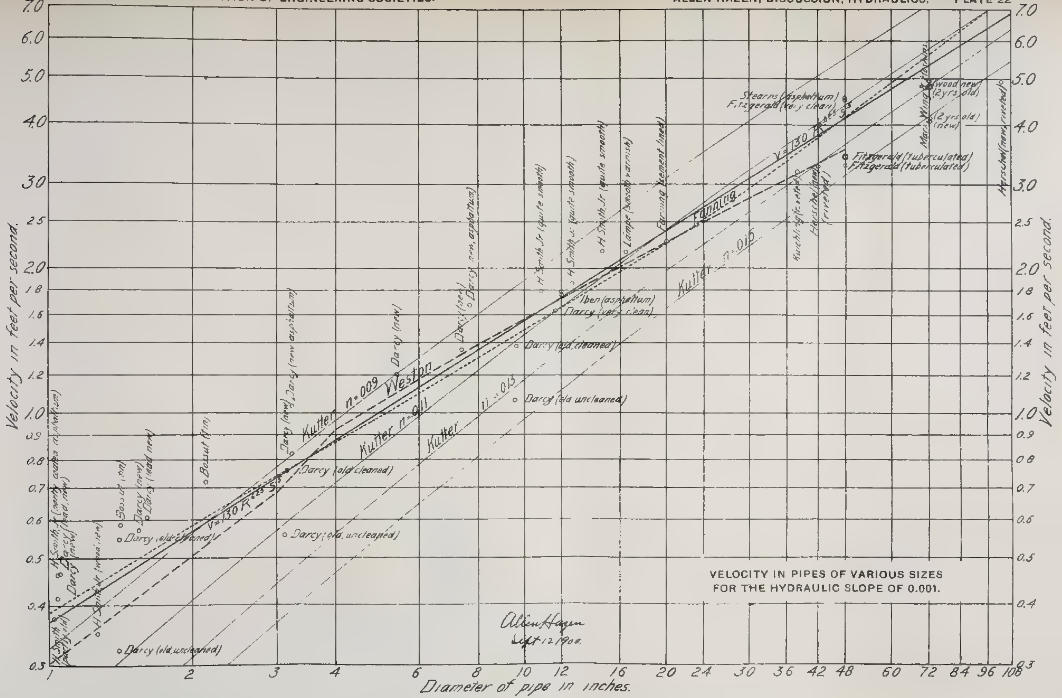
A method of estimating the value of x, which occurred to the author before he saw Tutton's paper, and which resembles somewhat Tutton's method, although the procedure is a little different, is the following: The value of y is assumed to be 0.50, and on this assumption the velocity of water in each size of pipe is computed for $S = 0.001$. That is to say, for the purpose of discussion, the various experiments are reduced to a constant value for S. This slope of 1 in 1000 was selected as convenient and as representing approximately the average slope in actual work,

although this is not essential. The velocities for $S = 0.001$ are then plotted on logarithmic paper with the sizes of pipe in inches. If the points should prove to be in an approximately straight line, the values of x and C could be determined from it and would be constant. Such a diagram, showing the results given in Fenkell's paper, is given herewith (Plate 22). I have followed Fenkell in his computation of constant error, and have taken into account only the value of the ratio between the velocity head and the friction, and from this I have computed, in each case, the velocity for $S = 0.001$. I have also plotted, upon the same scale, velocities given by Fanning for this slope, with the various sizes of pipe, and also the velocities shown by Weston's tables. Weston's tables do not show the precise velocity corresponding to a slope of 1 in 1000, so this value has been computed from the nearest values given. The corresponding velocities, computed by Kutter's formula, with n respectively 0.009, 0.011, 0.013 and 0.015, are also shown. This diagram shows clearly that Kutter's formula is not adapted to the computation of the flow of water through pipes, as with it the value of n varies almost as much as the value of C varies in Chezy's formula; and the use of Kutter's formula thus increases the complexity of computation without increasing the accuracy.

The tables of Weston and Fanning agree in a general way with each other, and with the experimental results herewith shown; but the minor curves in them are hardly warranted by any experimental data, and probably the straight line corresponding to the formula $V = 130\ R^{0.625}S^{0.50}$, which I have added, and which differs but little from them, is quite as accurate and more consistent.

It is, of course, not to be supposed that any formula could be derived in which the value of C would be constant; but if a formula should come into use in which the value of x was more nearly correct than in the Chezy formula, the variations in C would be correspondingly reduced, and discussion of results would become more satisfactory and more likely to lead to a correct understanding of the conditions controlling the flow. The value of x is certainly more than 0.50 and less than 0.75. Perhaps the existing data are not such as to warrant a very close approximation to an average value; but a figure could certainly be taken which is more nearly correct than the 0.50 used in the Chezy formula. It may be that originally the convenience in computation led to the selection of the exponent 0.50; but, with the facilities afforded by slide rules and logarithmic paper, there is


Velocity in feet per second.



VELOCITY IN PIPES OF VARIOUS SIZES
FOR THE HYDRAULIC SLOPE OF 0.001.

certainly no longer reason for continuing to use a round but incorrect figure because of the facility of computation.

In connection with the flow in very small pipes, it should be remembered that, with capillary tubes, x becomes 2 and y becomes 1, while the value of C depends in large measure upon the temperature of the water and its consequent viscosity. The conditions which control the friction in such tubes are undoubtedly quite different from those in large pipes, but it may be expected that the values of x and y will increase somewhat with very small pipes. Darcy's formula takes this into account in some measure, and new experimental investigations of the friction in small pipes would be of considerable interest.

In computing the actual flow of water through pipe lines, the following procedure has been found convenient: A table is prepared of the velocities and discharges in gallons per 24 hours for pipes of various sizes when the slope equals 0.001. To this is added a column showing those lengths of pipe in feet, in which the frictional loss is equal to the velocity head. As both the friction and the velocity head increase as the square of the velocity, this length is the same for all velocities. The following is such a table, based upon the heavy line in the diagram:

TABLE No. 2.

FLOW OF WATER IN PIPES.

$V = 130\ R^{0.625}S^{0.50}$. When $S = 0.001$.

Diameter in Inches.	Velocity, Feet per Second.	Gallons Daily.	No. of Feet of Pipe in which Friction Head is Equal to the Velocity Head.
1	0.37	1,300	2
2	0.56	8,000	5
3	0.73	23,000	8
4	0.87	49,000	12
6	1.12	142,000	20
8	1.34	303,000	28
10	1.54	544,000	37
12	1.73	877,000	47
16	2.07	1,867,000	67
20	2.38	3,354,000	89
24	2.67	5,412,000	111
30	3.06	9,720,000	147
36	3.43	15,690,000	184
42	3.78	23,510,000	224
48	4.11	33,400,000	264
54	4.42	45,500,000	306
60	4.73	60,000,000	350
72	5.30	97,000,000	440
84	5.83	145,000,000	533
96	6.34	206,000,000	630

This table is used with the slide rule as follows: The loss of head due to bends in pipe, entrance velocity, etc., in addition to the loss by friction in straight pipe, is usually expressed in multiples and fractions of the velocity head. These fractions are computed in the usual way and added up for the entire line, and the sum is multiplied by the length of pipe in the last column. The length so obtained is the length of straight pipe in which the friction loss is equal to the additional losses in the particular case under consideration. In other words all loss of head due to special resistance is reduced to an equal loss by friction in straight pipe. This computed length is added to the actual length of pipe, giving the length of straight pipe of equal resistance to the actual pipe line with bends, etc. One-thousandth of this length is the loss of head in feet, when the velocity and discharge are the amounts shown for that size pipe in the table. The index of a slide rule is put upon this amount (that is, the head) on the upper scale, and the moving part is set so that the marker shows the discharge in gallons, or the velocity in feet per second, on the lower or square root scale. If another value of C is desired, as, for instance, 100 instead of 130, for steel pipe or old tuberculated pipe, the scale can be moved a corresponding amount. The index can then be moved to show other heads and quantities, which can be taken off without further setting. This short table is readily put in a notebook, and with it and a slide rule the flow of water in pipes can be computed quickly and perhaps as accurately as by other methods.

Mr. Clarence W. Hubbell.—The writer desires to add his testimony to the statement of the author that the failure of the locus of the ratio existing between velocity head and frictional loss, to pass through the origin, indicates the presence of an initial error which should be eliminated before final reductions are made and conclusions drawn therefrom. During the past two years the writer has conducted a number of experiments on comparatively short lengths of cast iron water pipe connected with the distribution system of the Detroit Water Works, in which very delicate, specially designed and carefully calibrated difference gages were used, capable of indicating a loss of head corresponding to 0.002 of a foot of water on single readings, and much closer results when a number of readings were averaged. It was in each case possible to test the gages and gage connections under a condition of absolutely no flow, which should have given zero readings. The gages, however, could seldom be brought to read absolute zero, although a careful inspection would frequently bring to light some unsus-

pected leak or air bubble, the elimination of which tended to correct the apparent error.

In a series of observations on twenty-one consecutive sections of 30-inch pipe, the longest section being 667.86 feet and the shortest 23.51 feet, the observed frictional loss, with absolutely no flow, was: In four lengths, zero; in seven lengths, positive; in ten lengths, negative.

If the gages had never indicated zero, or if the apparent error had always been of the same sign, the failure to close might have been explained by some theory of internal motion. Under the circumstances, however, the only reasonable explanation seems to be that an initial error did exist in the gages or gage connections. In almost every case it has been found necessary to eliminate the initial error in order to obtain comparable results. In short lengths of large pipe, the error, while small in actual quantity, was frequently equal to the frictional loss corresponding to an initial velocity of one foot per second.

A constant initial error can be readily eliminated by the method adopted by the author, if the assumption that $H_f \propto H_v$ holds true; and this assumption seems to be fairly well established, within reasonable limits of error, for sizes of pipe above 12 inches in diameter.

However, errors which do not remain constant during a series of observations tend to make the locus of $\frac{H_f}{H_v}$ a curved line, and therefore cannot be eliminated by such a simple method. Indeed, it is usually impossible to eliminate such errors by any process of reduction whatever.

As to the two methods of plotting,—*i.e.*, $\frac{H_f}{H_v}$ and $\frac{\log H_f}{\log. V}$—, the writer believes that each system has its strong and its weak points. The first method (that adopted by the author) exaggerates errors at the upper end of the series and minimizes those near the zero point, which seems to the writer preferable to the exactly opposite tendency of the second method.

Again, the first method will detect and eliminate any initial error which remains constant throughout a series of observations, while the presence of such an error will cause the locus obtained by the second method to be a curved line convex on the upper side (log. H_f vertical ordinate):

(1) When H_f, as observed, contains a negative error or is less than the true frictional loss.

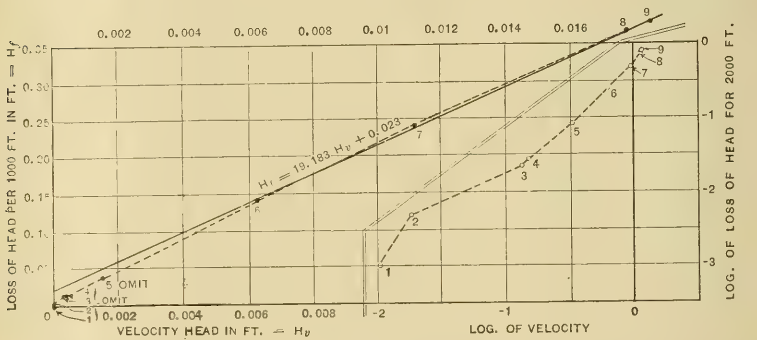
(2) When the velocity contains a positive error, or is greater than the true velocity, and concave on the upper side:

(3) When H_f, as observed, contains a positive error or is greater than the true frictional loss.

(4) When the observed velocity contains a negative error or is less than the true velocity.

On the other hand, as stated by the author, if no errors be present in the observations, a curved line, obtained by the first method, indicates that the frictional loss does not vary as the square of the velocity, but according to some other power which may be obtained by the second method. It therefore seems to the writer that, taking everything into consideration, the best general results are likely to be obtained by using the first method in reducing observations on pipes of large diameter, and the second method for those of small diameter, while in certain cases a combination of both methods may be used to advantage.

PLATE 23



The method used by the author in determining the average straight line, represented by a number of observed points, has one thing in its favor not mentioned by him,—viz, the fact that numerical results obtained are checked graphically where the three points are plotted. For, if they fall in an absolutely straight line, it is sufficient proof that no appreciable errors have entered into the derivation of ordinates; while, on the other hand, if they fail to fall in a straight line by ever so little, it is at once apparent that the reductions are in error and must be recomputed.

Plate 23 gives the results of an experiment on 2000 feet of 12-inch cast iron water pipe at very low velocities. The frictional loss was determined with extreme accuracy, to be used relatively with other results.

Incidentally, the velocity was computed from the register of a new 6-inch Thomson meter, in good condition, but which

has never been rated. Errors, if any, are those due to the error in registry of an ordinary 6-inch Thomson meter.

The observed points are numbered and plotted by both methods, thus illustrating the exaggeration of each system. The value of C, in $V = c\sqrt{rs}$, is 115.9, obtained by the method employed by the author, and averaging the four highest points.

The results are also given in Table No. 3:

TABLE No. 3.

EXPERIMENTS ON FLOW OF WATER THROUGH 2000 FEET OF 12-INCH TAR-COATED CAST IRON WATER PIPE CAREFULLY LAID TO LEVEL GRADE.

No. Readings Taken.	Loss of Head in Feet (Hf) per 2000 Ft.	Log. Hf.	Velocity, Feet, per Second.	Log. Velocity.	Velocity Head in Feet (Hv).	C in $V = C\sqrt{rs}$.
34	0.00102	—3.008600	0.01050	—2.021189	0.0000017	29.41
18	0.00504	—3.702431	0.01790	—2.252853	0.0000049	22.56
29	0.02268	—2.355643	0.13196	—1.120574	0.000269—	78.55
28	0.02516	—2.400711	0.15140	—1.180126	0.000556+	85.39
28	0.08628	—2.935910	0.32586	—1.513084	0.001648+	99.19
30	0.28209	—1.450388	0.63158	—1.800442	0.0062000	106.32
40	0.48842	—1.688794	0.85831	—1.933639	0.011449+	109.85
36	0.72661	—1.861301	1.06685	0.028124	0.0176897	111.90
38	0.74832	—1.874088	1.08571	0.035124	0.0183208	112.30

MR. GARDNER S. WILLIAMS.—Inasmuch as the writer was in a measure responsible for starting the investigation, the results of which have been presented in the paper entitled "A Study in Hydraulics," he feels that he may very properly apologize to a long-suffering public for the presentation again, below, of experiments that have been discussed by almost every writer on the subject of hydraulics since the close of the last century. No one realizes more fully than he that if one-half the time and energy that has been spent in discussing old and questionable observations had been expended in making reliable ones, the science of hydraulics would be much further advanced to-day, and no one more heartily appreciates the feelings of an eminent hydraulic engineer who recently exclaimed: "In the name of nineteenth century progress let us get through telling what the Abbé Bossut did in 1776." Nevertheless, if, after all its threshing over, there still remain, among the mass of chaff and straw, some kernels of grain that have escaped the sifting of those who have labored before, the writer feels that he is warranted in making one more examination of the well-worn data, and having, as he believes, found therein some evidence of the existence, not of new laws, but of some that have been apparently forgotten, or overshadowed by more recently discovered

ones, he offers this as his excuse for calling attention again to those old experiments of Bossut and others.

The assumption that the loss of head of water flowing in pipes of uniform cross section varies as the square of the velocity, upon which the investigation presented by the author is based, is the same as that upon which the Chezy and nearly every other flow formula rests, and is one that has been tacitly accepted with practical unanimity in nearly all hydraulic discussions; and, while such acceptance does not prove the assumption to be correct, it nevertheless goes far toward showing that, for the cases coming within ordinary practice, it is not very seriously in error. But in these days of rigorous requirements in all lines of investigations, it is in every way desirable that the correctness or incorrectness of all such assumptions be determined, and, if there are limits to the application of them, that those limits be ascertained as well.

The plates presented by the author show that in many of the series studied the line $H_f = a\ H_v$ does not pass through the origin, and this the author attributes to errors of observation. Such an interpretation is probably, in a measure, correct in every case, but the presence of an intercept $\pm$ b has another possible signification, *i.e.*, it may indicate curvature of the locus which is so slight as to be imperceptible except close to the origin, or in other words it may indicate that H_f does not vary exactly as H_v or V^2. Referring to Fig. 2, Plate 24, it will be seen that if $H_f \propto V^{1.70}$ there is an intercept $+ b = 0.7371$; if $H_f \propto V^{1.80}$ the intercept is $+ b = 0.5519$; if $H_f \propto V^{1.90}$ the intercept $+ b^f = 0.3191$, and if $H_f \propto V^2$ the intercept is zero and the line passes through the origin. From this it is at once apparent that the presence of a negative intercept on the H_f axis, or a positive one on the velocity head axis, may indicate that H_f varies as a higher power of V than the square. In examining the author's plottings, it is noticeable that in only twelve cases,—less than 20 per cent.,—does the line $H_f = a\ H_v \pm b$ cut the velocity head axis; *i.e.*, have a negative b and in all of these except 14a and 59 the intercept is so small that it may almost be neglected. In 59 it will be noted that the diameter is very great, and in five of the others giving a negative b the diameter is greater than 3 feet; on the other hand the $+ b$ intercepts are numerous and many of them of considerable magnitude, and are confined, with few exceptions, to the smaller sizes of pipe. The uniformity with which these $+ b$ intercepts appear on the smaller sizes is fair ground for the assumption that they are due to something more than errors of observation, since it is hard to account for the net result of such errors being always

of the same sign. This, taken with the fact pointed out by the author, that experiments with small diameters do not give straight lines when H_f is plotted to the velocity head, has led the writer to investigate this phase of the subject and to enquire whether any relation exists between the diameter and the exponent of V in $H_f = M V^n$ and if so, how the relation is affected by roughness and curvature in the pipes.

Reviewing the history of the matter we find that Prony, about the beginning of the present century, began to recognize the fact that the losses of head in flowing water did not vary exactly as the square of the velocity, and, in the Proceedings of the Royal Society for 1808, Dr. Thomas Young, in discussing his investigations upon the flow of water in pipes, says: "I began by examining the velocities of the water discharged, through pipes of a given diameter, with different degrees of pressure, and I found that the friction could not be represented by any single power of the velocity, although it frequently approached to the proportion of that power of which the exponent is 1.8, but that it appeared to consist of two parts, the one varying as the velocity and the other as its square. The proportion of the parts to each other must, however, be considered as different, in pipes of different diameters, the first part being less perceptible in large pipes or in rivers, but becoming greater than the second in very minute tubes, while the second also becomes greater for each given portion of the internal surface of the pipe, as the diameter is diminished." Dr. Young had at his disposal only the experiments of Couplet, Bossut, DuBuat, Gerard, Gerstner and himself, all of which were made with small pipes, except those of Couplet, which were confined to very low velocities.

In 1855, before the Institution of Civil Engineers,* discussing DuBuat's formula, we find Mr. Thomas Hawksley quoted as follows:

Reporter's Abstract.—"Mr. Hawksley was not aware of ever having stated, and he certainly never intended it to be understood, that the formula was applicable to all cases. It was applicable, however, to all cases which fell within the ordinary practical application of hydraulic science; but it was not applicable for those extreme cases of minute diameter and sluggish velocity, in which what ought to be really termed the friction of water, required to be taken into account. What was usually denominated friction, by writers on hydraulic science, was not friction at all, but was a resistance of impact, which varied as the square of velocity, and

*Min. Proc. Inst. C. E., 1855.

that was the great resistance experienced in the conduct of water, and was that given by the formula. In addition to this, there was another resistance which only varied as the simple velocity,—the resistance of adhesion or viscidity, as it had been called, but in reality of friction proper."

But having got so far in the explanation of phenomena of flow, Mr. Hawksley was led astray into the acceptance of the then universally adopted theory of DuBuat, of the fluid envelope and consequent non-effect of character of surface of the inclosing conduit, which later investigations, particularly those of Darcy, have shown to be wholly erroneous. The idea of two kinds of resistance to be dealt with is considered in some of the older formulæ of flow, although the terms providing for the real friction, were, in ordinary cases, so insignificant that the older hydraulicians themselves frequently omitted them, and in the popular Chezy formula they are wholly unrecognizable, the variation of the coefficient C being relied upon to provide for them. Mr. Edmund B. Weston, member American Society of Civil Engineers, after a very painstaking and exhaustive investigation of existing experiments, published in Volume XXII, Transactions American Society of Civil Engineers, concluded that the formulæ which best fitted the experiments with large pipes were not satisfactory for small ones, and for such pipes proposed a formula involving V^2 and $V^{3/2}$.

The writer has no inclination to present any new formulæ for the flow of water in pipes; but, continuing in the line of Mr. Hawksley's reasoning, with the advantage of our present and more correct knowledge of the influence of roughness of surface, he would call attention to the fact that the recent investigations as to the effect of such roughness have in a measure overlooked the coexisting effect of diameter. Hamilton Smith, Jr., has stated that C in the Chezy formula increases with the diameter and with the velocity. If the deductions of the author are correct, or even approximately so, they force us to account for the variation of C by the changes in diameter alone, leaving out, for the present, considerations of roughness. A high value of C in that formula generally means that the exponent of S or of R is also high, while a low value of C indicates a low value of the exponent of R or S, R and S being less than unity; for, if we accept as correct the experimental data in any case, it follows that V, R and S must be correct, and therefore the variation of the result by formula from the experimental one is due to errors in either coefficient or exponent or both, and any change in one may be compensated by corresponding change in the other for any specific case.

Insomuch as there is a very widespread misconception regarding the friction of liquids upon solids, for which the text-books themselves are in a measure responsible, it being often stated that the frictional resistances in flowing water increase as the square of the velocity, it may be well to draw attention to the fact, quite clearly proven by experiment, that the friction of water upon a solid, or upon itself when moving in straight lines, varies nearly as the first power, and not as the square, of the velocity. The opposite conception is at the foundation of a recent formula* for the flow of water, which, by one of those rare circumstances of two errors balancing each other, gives, in its resulting values, some remarkably close approximations to actual conditions. However convenient or useful this formula may be as an instrument, the basis upon which its derivation rests is radically wrong.

The flow of water through capillary tubes affords a case where internal resistances, those due to impact, must be almost wholly obliterated, and the loss of head observed must therefore be practically that due to skin friction, and all the accepted experiments in this field show that the loss of head varies very nearly as the first power of the velocity. In the flow of water through fine sands there is perhaps a more perfect example of the effect of skin friction alone, and here again the loss of head is found to vary as the first power of the velocity. If further evidence be required, the investigations of Prof. Osborne Reynolds show that so long as the motion of the particles of water in a pipe is rectilinear, the loss of head varies with the first power of the velocity, and if still more is asked reference may be made to the experiments of Rennie, Coulomb, Beaufoy, Froude and Unwin with various surfaces dragged or rotated in still water, in all of which the evidence is that until vibrations are set up in the water itself, the force required to maintain motion varies as some power of the velocity much below the second. It is to be remarked that in dragging or rotating any body in still water, it is practically impossible to separate the force overcoming true skin friction from that expended in creating motion in the adjacent water, and for this reason it is only at extremely low velocities that we would find the resistance to vary with as low a power as the first, but under these circumstances that power has been quite closely approximated.

In the case of water flowing at ordinary velocities, where the impact conditions have attained their normal importance the true friction—that varying as the first power of the velocity—is probably restricted mainly to the particles of water in contact with the

*Sullivan's Formula $V = CD^{3/4}\ S^{1/2}$ with $C = 50$ for cast iron pipe.

bounding surface, while the impact effects extend through the whole volume of the liquid, and it therefore appears that the ratio of importance of the two forms of resistance in determining the whole loss of head will be proportioned nearly to the ratio of the area of the cross-section to the wetted perimeter, which is R, and in circular pipes a function of the diameter alone. It is therefore seen that for pipes of uniform smoothness, when of large diameter, the resistance at the circumference is quite insignificant as compared with that in the interior, and that for very small pipes the condition is reversed, and it may be consequently expected that if in the equation $H_f = mv^n$ — in which H_f is the loss of head due to both forms of resistance,—*i.e.*, that usually indicated by the fall of pressure between two points in a closed pipe of uniform section after regular flow has become established, and V is the mean velocity of flow, and *m* a coefficient,—the value of *n* the exponent of V is determined, it would range from unity for capillary tubes as found by Poiseuille and others, to nearly *2* for large pipes, as demonstrated by the author's plottings.

Considering now the effect of roughness on this exponent, it may perhaps appear at first sight, that since the true friction must be greater in a rough than in a smooth pipe, the effect of increased roughness while undoubtedly increasing the coefficient *m* would be to decrease the exponent *n*. On the other hand it may also appear that a roughened surface will add to the internal resistances, and the increase in that function on that account may balance or even exceed the increase of the true friction, and the exponent remain unchanged or be increased. So it is hardly safe to prophesy the result of increased roughness without a careful experimental examination of the matter, and the latter is extremely difficult to manipulate in such a way as to afford the kind of evidence sought in the present case. The especial difficulty lies in the determination of a unit of roughness for it may be readily conceived that any number of pipes may have the same mean sections and yet have their maximum and minimum sections vary to an almost unlimited extent, so in dealing with the experimental data at hand no very definite agreements can be expected in the results of observations upon rough or tuberculated pipes.

For such an investigation of the question $H_f = mv^n$ as is proposed above, the most convenient method is by plotting the corresponding logarithmic equation, which is: $\log H_f = \log (mv^n) = \log m + n \log V$ and if *n* and *m* are constants this is seen to be the equation of a straight line, it being of the general form $y = ax + b$, and therefore the tangent of the inclination of the line to the

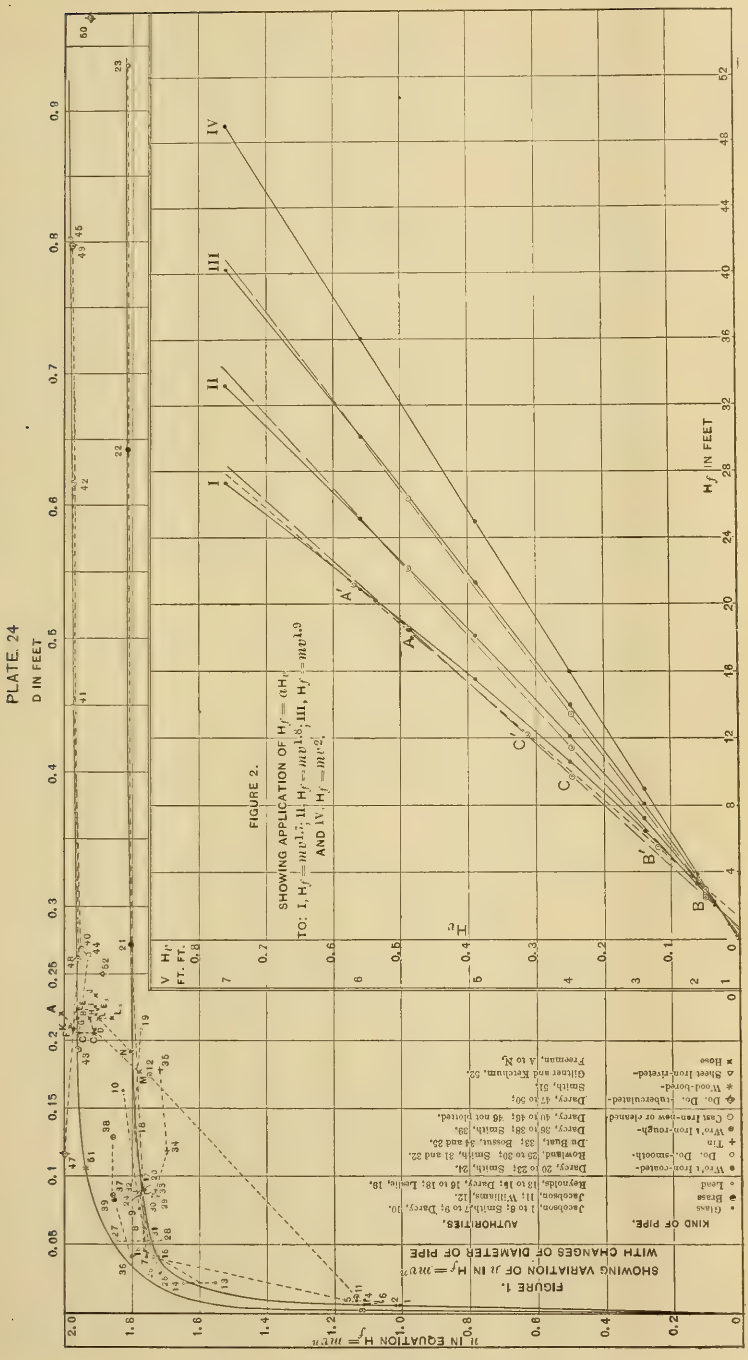


PLATE 24
D IN FEET
FIGURE 2.
SHOWING APPLICATION OF $H_f = aH_v$
TO: I, $H_f = mv^{1.7}$; II, $H_f = mv^{1.8}$; III, $H_f = mv^{1.9}$
AND IV, $H_f = mv^2$.
H_f IN FEET
V FT.
H_v FT.
FIGURE 1.
SHOWING VARIATION OF n IN $H_f = mv^n$
WITH CHANGES OF DIAMETER OF PIPE
n IN EQUATION $H_f = mv^n$
KIND OF PIPE. AUTHORITIES.
Glass — Jacobson, 1 to 6; Smith, 7 to 9; Darcy, 10.
Brass — Jacobson, 11; Williams, 12.
Lead — Reynolds, 13 to 15; Darcy, 16 to 18; Leslie, 19.
Wro't Iron-coated — Darcy, 20 to 23; Smith, 24.
Do. Do.-smooth — Rowland, 25 to 30; Smith, 31 and 32.
Tin — Du Buat, 33; Bossut, 34 and 35.
Wro't Iron-rough — Darcy, 36 to 38; Smith, 39.
Cast Iron-new or cleaned — Darcy, 40 to 46; 46 not plotted.
Do. Do.-tuberculated — Darcy, 47 to 50.
Wood-bored — Smith, 51.
Sheet Iron-riveted — Giltner and Ketchum, 52.
Hose — Freeman, A to N.

axis of x is the value of n and the length of the ordinate $log\ H_f$ at $(V = 1\ or\ log\ V = 0)$ is $log\ m$. This equation may, of course, be plotted and the results deduced by the use of a table of logarithms and ordinary cross-section paper, but by the use of logarithmic cross-section paper, for which the writer is indebted to Mr. John R. Freeman, Member American Society of Civil Engineers, the labor can be considerably reduced, without a great sacrifice of accuracy, and it is by this means that the results about to be presented have been obtained. In estimating their value it is to be remembered that this method in no way provides for the condition which the author has shown to frequently exist, of there being, as he concludes, a constant error in the observations of one sign, so that the experimental locus does not pass through the origin, and consequently the exponent value may be considerably affected by such causes without the reason being detected.

The writer has examined the results of over sixty series of experiments upon pipes with diameters ranging from 0.00575 feet to 0.9744 feet, made by fifteen different investigators under quite varying conditions.

The results of a part of these investigations are presented in the accompanying table No. 6, and are also represented graphically on Plate 24, Fig. 1.

In dealing with these experiments it must be remembered that they have been made under two quite different plans of observation. The first and oldest is that of allowing the water to flow from a reservoir into the pipe and to discharge either into the open air or beneath the surface of water in a second reservoir, the loss of head measured being that between the surfaces of water in the two reservoirs, or, when into air, between the center of the section of discharge and the surface in the feeding reservoir. The head so obtained is then corrected by the subtraction of the head required to produce the observed velocity and for an assumed loss due to the contraction at entry, the remainder being assumed to represent the loss of head in the pipe alone. This is the method of Couplet, Bossut, DuBuat, Leslie and Hamilton Smith, Jr., the latter especially favoring it, and strongly (though it seems not with entire justification) condemning the second method, that of Darcy, Jacobson, Rowland and Freeman, which consists of observing, by means of radial perforations in the pipe wall, the heads at different points in the pipe experimented upon, and by their difference obtaining directly the loss of head from one point to another. In the writer's opinion, when the piezometric openings and the section experimented upon are properly located, the latter

method is to be preferred. As to the method of measuring the discharge, whether by weight or volume, it has been passed upon and accepted by Hamilton Smith, Jr., in nearly all the cases cited, and in most of the remaining ones the intrinsic evidence of the results of the experiments when plotted goes far to establish the accuracy of the observed quantities.

It is conceived that less confidence is to be placed in experiments upon short lengths of pipes when made by the former of the two methods described, because it seems doubtful whether the effect of entry has ever been accurately determined or properly explained, and any error in allowing for this will have a greater influence upon the results in short than in longer pipes. For this reason greater weight is given to the work of Darcy than to that of the other observers, as from his work it is possible to take the loss of head in a section of pipe of a good length that is preceded by a longer section in which the effect of entry has had a fair chance to work itself out, and it may therefore be expected that the loss of head obtained will be the true loss under consideration, unaffected by any but normal conditions.

Darcy's pipes were attached to the end of a closed cylinder 3.28 feet in diameter and 9.76 feet long by a square joint. Manometer No. 5 was attached to this cylinder. Within 1.5 feet of this cylinder was manometer No. 4, and in all cases except that of the glass pipe and the lead pipes manometer No. 3 was placed 13 to 18 feet further down stream, manometer No. 2, 164 feet beyond that and manometer No. 1 another 164 feet distant, which was usually from 20 to 25 feet from the outlet. In the glass pipes manometer No. 4 was omitted and Nos. 3, 2 and 1 were separated by the distances 70.75 feet and 76.39 feet, the total length being 147 feet. For the lead pipes manometer No. 4 was 2.3 feet from the inlet, No. 3 was from 4.59 feet to 4.92 feet from No. 4 and Nos. 3, 2 and 1 were 82 feet apart, No. 1 being then about 1.1 feet from the outlet. All the manometers were attached to a single piezometric opening in the side of the pipe.

In reducing these experiments, the velocities as given by Hamilton Smith, Jr., have been accepted, but the slopes have been determined by the readings of manometers Nos. 1 and 2, not 1 and 3 as was done by other commentators and by Darcy himself. Using these slopes, instead of those for the longer section, the erratic results criticized by former investigators are very largely eliminated, and it was upon those incongruous results, which it appears were due to the proximity of the upstream piezometer No. 3, to the

inlet, that Hamilton Smith, Jr., based his severe arraignment of the piezometric method of observation.

In this connection it may be remarked that since piezometric openings in the pipe wall do not give the mean pressure head in the cross section, but only that in the layer of water next the opening, it follows that if for any reason the velocity of the particles in this layer at one point of observation is greater or less than at another the difference of the pressure heads observed will be increased or decreased as the case may be, by the head represented by the change of velocity between the two points. It is not, therefore, to be expected that a piezometric observation taken near a contraction or a curve or a gate in a line of pipe will give data comparable with that shown by similar openings elsewhere, so that the desideratum for this sort of observation is a long length of smooth, straight pipe preceding the section to be experimented upon. How long this preceding length must be is yet to be determined, but that it should be many times longer than has been heretofore supposed is proven by the experiments of Darcy, Jacobson and Reynolds, as well as by more recent ones which might be cited.

For the experiments of Hamilton Smith, Jr., the data as presented in his Hydraulics has been accepted, and from the same source have been taken the experiments of Bossut and DuBuat.

The experiments of James Leslie with 2½-inch lead pipe, 100 feet long, the only ones in his series which seem sufficiently reliable to be included here, have been computed from his data as presented in the Proceedings of the Institution of Civil Engineers of Great Britain for 1855, the observed heads being corrected for velocity, but not for entry. This pipe was coiled in a spiral 90 feet in diameter, the loss of head was measured by the difference of level of water in tanks at the inlet and outlet ends, and the discharge was measured in a tank.

The experiments of Thomas F. Rowland, given in Transactions American Society Civil Engineers, Volume XIX, have been similarly reduced. In these experiments the diameters were not measured, but the pipe is described as ¼-inch, ½-inch and 1-inch wrought iron. For these reductions the present standard diameters of these sizes of pipe have been taken and are given in the table. The discharge was determined by weight and the loss of head by Bourdon Gages. The experiments have been rejected by Hamilton Smith, Jr., with justification, but they are included here as the only ones on record with very small wrought iron

pipe, and for the smallest diameter the observations seem to be fairly consistent.

The experiments of Prof. Osborne Reynolds have been taken from the Royal Philosophical Transactions for 1883. These pipes were of lead ¼ and ½-inch diameter and 16 feet long. They were attached by trumpet mouthpieces to a tank, and the heads were read piezometrically at points five feet apart near the downstream end, the upstream piezometer being 9.6 feet from the inlet. In Professor Reynold's own discussion of these results he says that the loss of head varied as the 1.722 power in both pipes. From a study of the published data this conclusion appears erroneous. The value here obtained of 1.725 for n with the larger pipe is as close a corroboration as could be expected, but in the case of the smaller pipe the observations fall in two groups, separated from each other by a change in m the coefficient of V and apparently indicating an unsuspected change of condition. Each set has a perfectly definite and regular inclination when plotted logarithmically, and in both cases it is considerably below that of the larger pipe, being about 1.637 for the lower velocities and 1.551 for the higher ones. It appears that Professor Reynolds took both groups together and found n from the inclination of the line best fitting all observations; but this, from the appearance of the data, does not seem justifiable, and his conclusion is, moreover, antagonistic to the indications of the rest of the experiments investigated in the present discussion. The experiments themselves appear to have been made with great care and to be entitled to the highest confidence as representing accurately the conditions encountered.

The experiments of Dr. Heinrich Jacobson were made at Koenigsberg, and were published in the "Archiv für Anatomie, Hygiene," etc., in 1860 and 1861. The pipes were connected to a cylindrical reservoir by a conical brass mouthpiece. The losses of head were measured both from the surface of the water in the reservoir and from the height of a manometer column connected to the tube at a point at varying distances from the inlet, being generally, in the experiments selected, about 0.03 foot away; the pipes discharged freely into the air, so that the total head measured at this point was presumably the loss of head in the remaining section of pipe. The diameters were determined by weighing the water in the pipes, which had been previously selected from a large number for uniformity of bore. Distilled or filtered water was used, and the discharge was determined by weight. These experiments were very carefully made and show remark-

ably harmonious results, though it appears that the piezometer was in some cases too close to the inlet. With these small diameters the temperature has an important bearing, but those experiments only have been selected for the present investigation, in which it was either constant or of small range.

The experiments of John R. Freeman, member American Society Civil Engineers, upon hose have been taken from Volume XXI, Transactions American Society Civil Engineers, without alteration. It, however, seems that the length of 25 feet usually existing between the hydrant and the first piezometer was not sufficient for the elimination of entry effects, and that this accounts for some of the peculiarities of the series.

The experiments credited to Iben and Ehmann are given upon the authority of Hering and Trautwine's Appendix to "The Flow of Water in Open Channels." They lack completeness of data, as obtained from this source, and are presented only as being in a measure corroborative of the conclusions drawn from the more reliable investigations.

The experiments upon the 3-inch riveted pipe and the 2-inch brass pipe were made in the Hydraulic Laboratory of Cornell University during the latter part of 1899 and the early part of 1900. The former investigation was made by Messrs. L. C. Giltner and D. A. Ketchum, Jr., as a graduating thesis in the College of Civil Engineering, and the latter was made by the writer. The arrangement of the apparatus is shown in Plate 25. The water was taken from a tank in the top of the building, where the head was maintained constant by a float valve controlling the supply from the university reservoir, and admitted to the experimental system through the pipe D, which was of standard 2-inch wrought iron. By a similar pipe E it was conducted into the regulator chamber F F, in which it passed through a screen consisting of a brass plate drilled with $\frac{1}{8}$ and $\frac{3}{32}$-inch holes. The outlet of this chamber was a cycloidal mouthpiece G, whose curve was generated by a rolling circle of diameter equal to one-fourth that of the following pipe H, and rolling parallel to the pipe axis. The pipe H was of seamless drawn brass tubing 0.416 foot in internal diameter, and at its outlet was a similarly constructed cycloidal mouthpiece I, connecting to the seamless drawn brass pipe J, K, L, M, N, O, of which L was the experimental section used in the experiments of the writer here presented, although observations were also taken upon H, I, J and K.

The pipe O was standard 2-inch wrought iron and P was standard 3-inch wrought iron, as was also the outlet section U,

TABLE No. 4.

EXPERIMENTS ON 3-INCH RIVETED PIPE. BY L. C. GILTNER AND D. A. KETCHUM, JR.

Mean Diameter, 0.2502 ft.

Series I. Flow from A to C.								Series II. Flow from C to A.							
Section A B—L=24.24′.				Section B C—L=24.90′.				Section C B—L=24.90′.				Section B A—L=24.24′.			
No. of Exp.	Velocity in Feet Per Second. V	Loss of Head Per 1000′ in Feet. H_f	Coef. in $V = C\sqrt{rs}$. C	No. of Exp.	Velocity in Feet Per Second. V	Loss of Head Per 1000′ in Feet. H_f	Coef. in $V = C\sqrt{rs}$. C	No. of Exp.	Velocity in Feet Per Second. V	Loss of Head Per 1000′ in Feet. H_f	Coef. in $V = C\sqrt{rs}$. C	No. of Exp.	Velocity in Feet Per Second. V	Loss of Head Per 1000′ in Feet. H_f	Coef. in $V = C\sqrt{rs}$. C
112	0.5121	0.635	80.7	112	0.5121	0.70	75.6	42	0.5633	0.88	75.1	42	0.5633	0.805	79.1
119	0.7815	1.420	82.5	119	0.7815	1.53	79.1	34	0.8439	1.85	77.5	34	0.8439	1.700	81.0
124	0.9236	1.970	82.8	124	0.9236	2.17	78.5	31	0.9395	2.25	78.0	31	0.9395	2.050	82.2
128	1.0268	2.400	83.2	128	1.0268	2.64	79.2	25	1.1037	3.09	78.7	25	1.1037	2.800	83.1
40	1.1633	2.970	85.1	40	1.1633	3.31	80.2	22	1.1914	3.60	78.9	22	1.1914	3.240	83.3
46	1.2290	3.330	84.4	46	1.2290	3.69	79.9	21	1.2063	3.69	78.4	21	1.2063	3.320	83.0
30	1.2439	3.340	85.6	99	1.3539	4.39	81.0	14	1.3585	4.55	79.7	14	1.3585	4.180	83.5
99	1.3539	3.980	85.3	37	1.4766	5.16	81.6	11	1.4109	4.95	80.0	11	1.4109	4.500	83.5
37	1.4766	4.660	85.4	27	1.5727	5.84	81.8	8	1.5227	5.65	80.3	8	1.5227	5.140	84.5
27	1.5727	5.240	86.5	38	1.6833	6.61	82.0	4	1.5882	6.13	80.4	4	1.5882	5.600	84.4
38	1.6833	5.970	86.6	95	1.7872	7.45	82.2	3	1.6326	6.51	80.3	3	1.6326	5.950	84.4
74	1.8715	7.340	86.9	93	1.8524	8.00	82.4	70	1.7454	7.35	80.7	90	1.7675	6.850	85.0
72	1.9331	7.790	87.0	104	1.9499	8.83	82.3	67	1.8387	8.10	80.9	88	1.8480	7.460	85.0
70	1.9876	8.260	86.8	106	1.9980	9.30	82.0	64	1.9446	8.99	81.4	85	1.9394	8.150	85.4
66	2.1207	9.280	87.8	88	2.1091	10.20	82.8	59	2.0945	10.32	81.5	81	2.0788	9.350	85.4
64	2.1627	9.640	87.8	87	2.1553	10.61	82.9	57	2.1386	10.75	81.6	79	2.1658	10.080	86.0
61	2.2538	10.400	87.8	85	2.2308	11.30	83.3	53	2.2496	11.79	82.1	76	2.2581	10.860	86.0
58	2.3229	10.920	88.4	80	2.3189	12.13	83.1	50	2.3273	12.47	82.4	72	2.3304	11.420	86.5
No. of Constrictions, 48.				No. of Constrictions, 50.				No. of Constrictions, 50.				No. of Constrictions, 48.			

Temperature of Water, 36° to 42° Fahr.

the last reducing to 1-inch pipe with a controlling valve V. The riveted pipe was comprised in the four sections Q, R, S and T. It was made of galvanized iron 0.0503 inch thick, which was rolled into conical joints 7 inches long and riveted with 1 longitudinal lap-seam having 7 rivets with a pitch of 1 inch. These joints were riveted together with a single circumferential row of 9 rivets with a pitch of 1.05 inches. These rows were 6 inches apart longitudinally. The rivets, both longitudinal and circumferential, had button heads $\frac{5}{16}$ inch in diameter at the base and $\frac{3}{32}$ inch high. The joints were then made tight by soldering on the outside of the pipe. The flange unions were so put on as to allow the lengths to telescope in the same manner as the minor sections, but the circumferential rivet rows were replaced at these joints by eight rivets with heads ½ inch in diameter at the base and $\frac{3}{16}$ inch high, fastening one flange to the pipe; the second flange, on the next section, was fastened by a similar row 3 inches away, and 3 inches from the next regular circumferential rows of 9 small rivets. The joints in the brass pipe were made with flanges. The ends of the pipes, being turned true in a lathe and the burr scraped from the inside, were butted tightly and held by the flange bolts, a guide having been also turned in the flange to hold the two ends truly in line.

The entire experimental pipe system was suspended from hangers in the ceiling and the center line was very nearly level for its entire extent.

The diameters were determined by calipering the ends of the individual lengths. With the brass pipe, the lengths ranging from 11 to 17 feet, two diameters at right angles were calipered at each end. The riveted pipe was calipered on each side of the longitudinal lap and at right angles to the diameter through the lap, the arithmetical mean of these caliperings being accepted as the value of D. The calipers used were made by Darling, Brown & Sharp, and were read to 0.0001 inch. The lengths were measured with a steel tape. The discharge was determined by weight upon a scale of 4000 pounds capacity, whose error was determined by comparison with a standard to be $\frac{1}{1140}$, and the correction neglected. The losses of head were measured piezometrically by differential gages of a special type, designed by the writer, with which differences of head amounting to 0.0006 foot of water could be readily detected. Readings were taken once each minute. The piezometric openings were radial and 90° apart, and in the case of the brass pipe were $\frac{1}{16}$ inch in diameter and communicated directly to a circumferential chamber, while with the riveted pipe

they were ⅛ inch and communicated by short ¼-inch diameter tubes with an equalizing chamber of 1-inch pipe. The gages were connected by ⅜ and ½-inch diameter rubber hose to the circumferential or the equalizing chambers.

The duration of a single experiment was not less than five minutes, the flow having been previously started and the water allowed to run to waste for three or four minutes through one

TABLE No. 5.

EXPERIMENTS ON 2-INCH BRASS PIPE. BY G. S. WILLIAMS.

Length, 46.376 feet. Mean diameter, 0.1738 feet.

Experiment.	Velocity in feet per second.	Loss of head per 1000′ in feet.	
a	0.53984	0.96	Temperature of Water, 39° to 46° Fahr.
b	1.1130	3.49	
c	0.75410	1.79	
d	0.69561	1.58	
e	0.59857	1.15	
f	0.56929	1.09	
g	0.39456	0.54	
h	0.25446	0.27	
i	0.53857	0.98	
j	2.0914	10.34	
k	1.8371	8.27	
l	1.6144	6.65	
m	1.2735	4.42	
n	1.0570	3.09	
o	1.3655	5.00	
p	0.47837	0.76	
q	1.1216	4.06	
r	0.82243	2.04	
s	2.1432	10.66	
t	2.2535	11.34	
u	1.9801	9.25	
v	1.6391	6.71	
w	0.92584	2.48	

side of the discharge spout W, which was divided by a vertical diaphragm. At the proper time this spout, which was suspended so as to swing freely, was swung over until the jet discharging at V was delivered into the other half of W and to the scale. The time required for thus diverting the flow was less than one second. The time was taken with an ordinary watch, and may be considered accurate within three seconds. In the riveted pipe experiments the water was brought to rest at the close of each experiment, and the static reading of the gages observed. In the brass pipe

investigation, static readings were taken once in five or six experiments. Dynamic readings were then corrected by the mean of the static readings at the beginning and end of the experiment. The riveted pipe was first experimented upon with a flow from A to C, being from the large to the small end of the sections, and then was reversed so that the flow took place from C to A and against the butts of the joints.

The experiments of Messrs. Giltner and Ketchum embraced observations upon two sections of the pipe, A B and B C, whose lengths were 24.24 feet and 24.90 feet, respectively, in the first series, and C B and B A in the second series. The observations on both sections were made simultaneously up to velocities of 1.75 feet per second, and separately for higher ranges. The plotting of these experiments upon logarithmic cross-section paper gives the following values for the loss of head per 1000 feet in feet of water, H_f.

For upstream section A to B, $H_f = 34.36\ v^{1.872}$.

For downstream section B to C, $H_f = 38.01\ v^{1.884}$.

For upstream section C to B, $H_f = 39.10\ v^{1.882}$.

For downstream section B to A, $H_f = 35.61\ v^{1.892}$.

It is notable that the section A B gives a lower loss of head per thousand, both direct and reversed, than the section B C. This section was slightly curved in the portion Q or that near the A end, the deflection from a straight line in continuation of the axis of the rest of the pipe being about two incnes. The pipe being made up by hand was none of it so straight as could be desired, but the curvature near A was the greatest anywhere. Owing to the short lengths used, general deductions from the observations may be misleading, although the writer doubts if there are many series of observations on record that have been more carefully conducted. The results do, however, quite clearly and consistently show what they were primarly undertaken to investigate,—viz, the effect upon the loss of head of reversing the flow in such a pipe, and prove that the resistance is increased when the flow takes place against the butt ends of the joints. They seem also to indicate that the effect of the expansion in the pipe area near the inlet end (from *O* to *P*, *O* being a piece of 2-inch and *P* a piece of 3-inch wrought iron pipe, the diameters being approximately 2.067 and 3.067 inches, respectively) is to decrease the apparent loss of head in the section immediately following. Other experiments have shown this to be the case with a contraction, and it is perhaps not surprising that the same effect should appear with an expansion.

The entire series of the experiments of Messrs. Giltner and Ketchum is plotted with loss of head as ordinate and velocity head as abscissa, upon Plate 26, and the reduced results of seventy-two observations from the series are given in table No. 4, as computed by the experimenters, and similar data for the twenty-three experiments by the writer are given in table No. 5.

Table No. 3 gives the elements of the several series of the experiments used in the plottings shown on Plate 25, Fig. 1. Data with numbers having subscripts are not included in the plate on account of the special conditions of those experiments, but are included in the table for purposes of comparison.

Considering now Fig. 1, Plate 24, the values of n in the equation $H_f = mv^n$ are plotted as ordinates and the values of the diameter D as abscissas.

The first thing noticed is that the values of n for the small diameters decrease quite rapidly when D is less than 0.1 foot, and that the values of n are lower for the smooth pipes than for the rough ones.

In the series with glass pipes, Nos. *1* to *10*, inclusive, there is first a set of six points from Jacobson covering three very small diameters, but which show n to increase with some power of D. Then there are three points, Nos. *7*, *8* and *9* from Smith, giving as many diameters and one from Darcy, No. *10*. No. *7*, of Smith, appears to be high, and from the table it is seen that this was a very short pipe as compared with the others of the larger diameters, being only about 11 feet long, while the next in length, No. *8*, was 35 feet.

On brass pipe there are only two points, Nos. *11* and *12*, and these being by different observers are perhaps surprisingly coincident in showing that the value of n for brass is less than for glass.

On lead pipe are three points from Reynolds, Nos. *13*, *14* and *15*, giving two diameters, three by Darcy, Nos. *16*, *17* and *18*, giving three diameters and No. *19*, by Leslie, which it will be seen falls below the value of n to be expected from the others. It is recalled, however, that this pipe was coiled in a long spiral, and it may be at this point suggested that curvature possibly has the effect of lowering the value of n. In the table, experiment No. *19, a*, by Iben, gives a value for n of 1.728 for D = 0.082. This experiment was rejected by Hamilton Smith, Jr., and the data available is incomplete. It is, however, not far away from the Darcy value for D = 0.0886 of 1.765.

On coated wrought iron pipe the points, Nos. *20*, *21*, *22* and *23* are from Darcy with sheet iron pipes coated with bitumen, and the point No. *24* is by Smith with a wrought iron pipe similarly coated, which comes very close to the Darcy value No. *20* for practically the same diameter.

Under smooth wrought iron are included only the experiments with modern pipes, as there is fairly good reason to suppose that the art of producing smooth interiors in Darcy's day was not so well perfected as in the time of the later experiments, and it is seen that the two experiments of Smith, *31* and *32*, fall very close to the lead pipe values, while the Rowland small pipe values, *25* and *26*, fall somewhat above. As already said, the reliability of Nos. *27* to *30* is considered questionable. Referring to the table the value of n for Hamilton Smith's short wrought iron pipe, 16 feet long is 1.842, while the value, *No. 32*, for a longer length, 60 feet, of the same size, is only 1.772, which corroborates the inference in the case of the glass pipes that short lengths, when treated by the Smith method of observation, give high values of n.

This conclusion is contradicted by the experiments of DuBuat on tin pipes, where, as shown in *33* and *33 a* of the table, the exponent for a length of 65 feet is 1.730 and for a length of 10 to 12 feet 1.686. Hamilton Smith has expressed the opinion that as an experimenter DuBuat was less expert than Bossut, and the added fact that in these experiments the discharge was part of the time into air and part of the time under water, warrants the questioning of this evidence as against that of Smith, which latter is further corroborated by the Rowland value for the 30-foot length of ¼-inch pipe No. *30 a*. The points from Bossut for tin pipes, Nos. *34* and *35*, show very low values of n decreasing with the diameter, and not far from the brass pipe value obtained by the writer.

The next set of points is from Darcy, with his wrought iron pipe, Nos. *36*, *37* and *38*, which, as explained above, is considered to have been more rough than the pipes of Smith and Rowland. This conclusion is strongly supported by the coincidence of the Smith point, No. *39*, on an old wrought iron pipe, 60 feet long, with No. *37* of Darcy on essentially the same diameter. These values it is seen fall about midway between the smooth pipe series and those of the rougher cast iron.

For cast iron, new and cleaned, there are six points plotted from Darcy. These pipes were not coated. No. *46* is beyond the range of the plate and it is not considered as reliable as the

others, probably on account of the large diameter and slow velocities. The author's plotting of these observations, No. *58*, Plate 3, shows the irregularity of the results. Nos. *40*, *41* and *42* are with new pipes, and Nos. *43*, *44* and *45* with old pipes that had been cleaned. The series as a whole shows very clearly an increase in n as the diameter increases.

With the exception of No. *50*, the points from the Darcy observations on tuberculated pipes corroborate the general conclusion that roughness increases the value of n.

Strange as it may seem, there is, outside of Darcy's work, a scarcity of good experimental data on cast iron pipes of the smaller diameters. From the experiments of Ehmann (see tables Nos. *46 a* and *46 b*) values for n of 1.822 and 1.912 are obtained for a diameter of 0.164, the latter of which comes somewhere near the Darcy curve; but the former does not fit at all. These experiments failed to pass the severe scrutiny of Hamilton Smith, Jr., and as they were made upon street mains having bends and other obstructions they cannot be considered of equal value with Darcy's work, but they may possibly be considered as adding their mite to the evidence that curvature decreases the value of n. Being coated, they were also probably smoother than were Darcy's pipes, and hence should give a lower value of n.

Hamilton Smith's wood pipe, made by boring with an auger a log of wood, probably gave a condition of surface not very different from that of cast iron pipe such as Darcy had,—*i.e.,* uncoated cast iron, and the plotting of this point *51* seems to be quite consistent with the Darcy values for cast iron.

The experiments of Messrs. Giltner and Ketchum, No. *52*, show the value of n to be considerably above the Darcy smooth pipes, and corroborates the conclusion that roughness increases the value of n.

The Freeman experiments upon hose do not give as satisfactory information upon the effect of diameter as had been hoped. This is probably partly due, as before suggested, to the comparatively short length of hose between the hydrant and the upstream piezometer, and partly to the many varying conditions encountered, as roughness, elasticity, very slight sinuosity, constriction at couplings, etc., all of which may be very likely to have an influence upon n. These experiments do, however, afford most interesting evidence as to the effect of sinuosity and curvature. In sample E, with the hose laid straight, $n = 1.961$, and when allowed to assume a sinuous position, the curves having a radius of about

six to eight feet, the value of n is reduced to 1.904. Similarly sample L, when straight, gives $n = 1.900$, and when sinuous 1.860.

Experiments upon the effect of curvature were also made with hose D, which are designated by the letters V, W, X, Y and Z in the table.

In V the hose in its middle portion was bent around four 45° curves of 2 feet radius. In W it was coiled around a full circle 2 feet in radius. In X it was bent around four 90° curves of 2 feet radius. In Y it was bent around four 90° curves of 3 feet radius, and in Z it was similarly bent around four 90° curves of 4 feet radius. The curves were arranged one left, two right and one left, a length of tangent equal to their radius being laid between each pair of curves. Fifty feet of hose A was connected between the upstream piezometer and the hydrant, thus improving the conditions over those of the original experiments with this hose. As originally tested, hose D gave a value for n of 1.911. At the beginning of these curve experiments it was again tested straight, D′ in table, and gave $n = 1.891$. At the close of the curve experiments it was again straightened out and gave $n = 1.873$, D″ in table.

When curved, it uniformly gave a lower value of n, the minimum being for X where $n = 1.803$, and the highest being that for the full circle where $n = 1.858$, all of which strongly confirms the inference drawn in considering the Leslie experiment that curvature tends to decrease the value of n.

As indicated by Mr. Hawksley, and since proven by Professor Reynolds, under certain conditions, even in pipes of considerable size, the resistance at low velocities increases as the first power of the velocity up to a certain critical velocity, the flow below this velocity being nearly rectilinear. This critical velocity appears to be somewhat dependent upon the diameter of the pipe. In the logarithmic plotting of several of the series of experiments, it has appeared that the low velocities gave low values of n, which gradually increased as the velocity increased until a velocity was reached above which the locus became a straight line showing n constant. In determining the values of n in this investigation, we have rejected in every case the curved portion of the locus and have taken for n its constant value.

Professor Reynolds was able to observe only the conditions indicating the establishment of a critical velocity when the water entered his pipes from a state of prolonged rest in his tank, and it is to be noted that in the writer's own experiments upon the brass pipe, and in those of Messrs. Giltner and Ketchum upon

the riveted pipe, in both of which velocities as low as one-fourth of a foot per second were observed, which are the lowest recorded for pipes of their sizes, there is no evidence of the exponent of V changing in value appreciably. Therefore the probability of the critical velocity, as Professor Reynolds defines it, being a factor in the engineer's practical computations, may be considered as questionable.

To summarize the results of this investigation, we find:

a. That the loss of head in pipes increases with a power n of the velocity, which power increases with the diameter from about unity in capillary tubes to about 2 for the larger sizes of water pipes.

b. That n increases with increased roughness.

c. That n decreases with increase of curvature from the straight pipe.

d. That the material of the pipe seems to have an influence upon the value of n.

e. That for the cases of pipes coming within the range of the engineer's practice, 2-inch diameter and above, the value of n may range from 1.8 for very smooth pipes, to about 2.0 for ordinary uncoated cast iron.

f. That when the loss of head is measured in the manner of Bossut, DuBuat and Smith, a short pipe will give a value of n that is high as compared with longer pipes, which seems to be on account of the special resistance generated at entry to the pipe.

To show graphically the effect of the application of the equation $H_f = a\ H_v$ to cases where the exponent of V is less than 2, there are plotted in Fig. 2, Plate 24, as abscissas, to the velocity head as the ordinate, the values of H_f when: I, $H_f = mV^{1.70}$; II, $H_f = mV^{1.80}$; III, $H_f = mV^{1.90}$, and IV, $H_f = mV^2$ for V = 0.5′, 1.0′, 1.5′, 2.0′, 3.0′, 4.0′, 5.0′, 6.0′ and 7.0′. The straight lines A, C, B for the three curves have been plotted according to the method presented by the author using all the points and in the case of $H_f = mV^{1.70}$ the line A′, C′, B′ has been similarly computed, using only the values of V from 1.5 feet to 7.0 feet, inclusive.

These plottings demonstrate that, although the lines may fit the points with considerable accuracy, they do not rightly pass through the origin, although the true curve does. They also show that for a range of velocity from 1.5 feet to 7.0 feet, which covers that ordinarily met with in pipe experiments, the straight line gives a very close approximation to the true curve, even in the extreme case of the exponent being as low as 1.70.

The equations of these lines A, C, B, are: I, $H_f = 36.504 H_v + 0.7371$; II, $H_f = 44.147 H_v + 0.5519$, and III, $H_f = 53.299 H_v + 0.3191$, and that of the line A′, C′, B′ is $H_f = 35.02 H_v + 1.327$.

With a clear understanding of the limits to the applicability of the straight line equation, it will be found a great assistance in the field and elsewhere in determining the approximate accuracy of work as it proceeds or is brought up for examination. As the author has pointed out, it is actually unnecessary to compute or use the velocity head itself, since the square of the velocity follows the same law, and may be therefore used in its stead, so that the labor of applying the straight line criterion is considerably less than might at first be supposed.

From the graphical method of obtaining the values of n in this investigation it follows that the third decimal place is beyond the limit of accuracy. The second is certainly as far as the accuracy can be relied upon, and that is chiefly valuable for comparison with the other values as given here. Another investigation treating the same data by the same process might very probably obtain values of n differing in the second place from those here presented.

The plottings of the author for large pipes indicate that there may be some very interesting developments at that end of the series, for they appear to show that n may have a higher value than 2, a point which is corroborated by some of Coulomb's experiments. The problem then naturally arises: Since the true friction varies as the first power, and the losses due to impact as the square of the velocity, and these are the principal causes now recognized as retarding flow, can a value of n greater than 2 be accounted for, unless it is admitted that the mean of the velocities of the individual particles of a flowing stream increases more rapidly than does the mean velocity of the stream as a whole?

Mr. John C. Trautwine, 3d.—In a series of tests on water meters to determine the relations between resistance and velocity, the writer made a few experiments on meters from which all moving parts had been taken, and also a few experiments on short lengths of pipe with connections of various kinds. While these experiments do not give results for straight pipe alone, yet they all go to show that, in the formula $v^n = 2\,g\,h$, the exponent n is by no means invariably $= 2$; that it is usually less, and that it increases with the projections and roughnesses. Thus, lengths of 1½ to 3 feet of small tubes, with couplings and meter unions, gave $n = 1.81$ to 1.83; but the insertion of defective packings in the meter unions,

TABLE No. 6.—EXPERIMENTS WITH SMALL AND MEDIUM-SIZED PIPES.

Discussed by $H_f = mV^n$ by Logarithmic Paper.

Chart No.	Authority.	No. of Obs.	Kind of Pipe.	Diameter in Feet.	Range of Velocity, Feet per Second.	Total Length, Feet	Length Used, Feet.	Value of n.
1	Jacobson	4	Glass	0.00575	1.895— 2.654	1.802	1.782	1.011
2	"	4	"	"	2 073— 2 641	1.700	1 670	1 014
3	"	5	"	0 00587	1.351— 1.896	0 921	0 864	1.113
4	"	3	"	0.00753	1.302— 2 629	1.434	1 404	1 114
5	"	2	"	"	3 169— 3 370	"	"	1 134
6	"	3	"	"	2.588— 3.189	1 700	1 670	1.062
7	H Smith, Jr	4	"	0.04180	1.955— 5 010	11 127	11.127	1 755
8	"	4	"	0 06220	1.398— 4.370	34 941	34 941	1 763
9	"	5	"	0 07640	2 077— 4 440	63 902	63.902	1.777
10	Darcy	6	"	0 16300	0 502— 6.920	147 200	76 390	1.824
11	Jacobson	7	Brass	0 00940	1.393— 2 305	2 035	2 005	1.129
12	Williams	23	"	0 17380	0.254 — 2.250	113 150	46 376	1.747
13	Reynolds	9	Lead	0 02017	8.773—15.385	14 600	5 000	1.551
14	"	10	"	"	2 371 – 8 731	"	"	1.637
15	"	33	"	0 04150	1 143—21.390	"	"	1 725
16	Darcy	7	"	0 04590	0 131 – 4 230	172 000	82 020	1.761
17	"	7	"	0 08860	0 213— 5 510	172 400	"	1 765
18	"	7	"	0 13450	0 394— 7 560	"	"	1.790
19	Leslie	8	"	0 20830	0 276— 6 900	100 000	100 000	1.773
19a	Iben	5	"	0.08200	2 700— 9 110	350 300 ?	350 300	1.728
20	Darcy	12	Sheet iron, coated	0.08790	0 980— 8.230	371 800	164 050	1.760
21	"	12	" " "	0.27100	0 328—12.790	365.100	"	1 801
22	"	11	" " "	0 64300	0.591—19.720	365 300	"	1 814
23	"	7	" " "	0 93500	1 296—10.520	365 500	"	1 816
24	H. Smith, Jr.	4	Wrought iron, coated	0 08730	2.220— 5.440	60.264	60.264	1.772
25	Rowland	3	Wrought iron, new	0 03030	9.190—12.130	60 000	60.000	1.712
26	"	3	" " "	0 03030	11.760—16 260	30 000	30.000	1.714
27	"	3	" " "	0.05190	17.000—22.730	64.000	64 000	1.844
28	"	3	" " "	0 05190	22.120—31 570	32.000	32 000	1.705
29	"	3	" " "	0 08730	18 120—24.730	97.000	97.000	1.730
30	"	3	" " "	0 08730	24.290—33.310	63.500	63 500	1 740
30a	"	3	" " "	0 08730	32 830—43 800	31.000	31 000	1.852
31	H Smith, Jr	6	" " "	0 05240	1.029— 3 880	60 127	60 127	1.747
32	"	14	" " "	0 08780	0 958— 5 390	60.172	60 172	1.772
32a	"	4	" " "	0 08760	2.333— 6.880	16.685	16 685	1.842
33	Du Buat	11	Tin	0 08880	1 410— 2 540	65.146	65 140	1.730
33a	"	5		0 08880	0.772— 7.540	10 39 & 12 30	10 39 & 12 30	1 686
34	Bossut	16		0 11840	1.116— 3.060	63 95 to 191 84	63 95 to 191.84	1 691
35	"	12		0 17850	1 455— 3 820	"	"	1 717
36	Darcy	13	Wrought iron, rough	0.04000	0 113— 3 930	374 600	164 050	1 800
37	"	13	" " "	0 08730	0.190— 7 170	372.200	"	1 858
38	"	12	" " "	0 12960	0 205— 8 520	371 900	"	1 855
39	H Smith, Jr	7	Wrought iron, old	0 08530	0.910— 4.270	60.250	60 250	1 857
40	Darcy	13	Cast iron, new	0 26870	0.289—10 710	366 100	164 050	1 950
41	"	10	" " "	0 44950	0 489 —15 400	365.700	"	1 974
42	"	9	" " "	0 61680	0.673—16 170	365 400	"	1.978
43	"	7	Cast iron, cleaned	0 11940	0 371— 3.690	374.900	"	1.960
44	"	7	" " "	0.20280	0 633— 5 010	366 300	"	1.930
45	"	8	" " "	0 80280	0 912—14 750	365.300	"	1 992
46	"	9	Cast iron, new	1 64040	1 380— 3 700	"	"	1.942
46a	Ehmann	4	Cast iron in use	0 10400	0 610— 2.950	2,138.600 ?	1,262 800	1 822
46b	"	6	" " "	"	0.840— 2 200	2,138 600 ?	2,138.600	1 912
47	Darcy	7	Cast iron, tuberculated	0 11780	0 167— 2 080	374 900	164 050	2 000
48	"	6	" " "	0 26080	0 403— 3 750	366 300	"	1 960
49	"	8	" " "	0.79790	1.007—12 580	365.300	"	1.983
50	"	8	" " "	0 97440	1 380— 3 700		"	1 942
51	H Smith, Jr	5	Wood, bored	0 10520	1 653— 3 990	62 050	62 050	1 934
52	Giltner & Ketchum	222	Riveted sheet iron	0 25020	0 183 – 2 330	54 080	24.900	1 883
A	Freeman	5	Hose, solid rubber	0 22080	12 500—20 000	178.000	152 900	2 013
B	"	4	" " "	0 21670	11 600—18 140	179 500	154 500	1 926
C'	"	4	Hose, rubber lined	0 20580	13 450—18 700	173 600	154 600	1 959
C	"	5	" " "	0 20580	13 400—20 000	180.000	161 500	1 915
D	"	10	" " "	0.20750	13 200—21 000	107 & 205	57 & 170	1 911
E	"	6	" " "	0 22330	7 500—17.800	178 000	153 200	1 961
Es	"	3	" " "	"	11 610—13 550	"	"	1 904
F	"	5	" " "	0 20830	11 620—22 000	76.700	51 700	1.972
G	"	5	" " "	0.21670	12.320—19 000	180.600	155.600	1 960
H	"	12	Hose, rubber lined mill	0 21830	11 070—19 500	183 & 341	158 & 316	1.908
I	"	4	" " " "	0 22420	11 500 – 18 000	182.000	157 000	1 908
J	"	5	Hose, Leather	0 23330	10 500—15 600	127 300	102.300	1.908
K	"	21	Hose, rubber lined mill	0 21080	3 500 —19 000	137 to 363	112 to 338	1.982
L	"	15	Hose, unlined linen	0.21670	3 500 20 000	180.000	154.900	1.900
Ls	"	4	" " "	"	7.270—13 500	"	"	1.860
M	"	5	Hose, rubber lined	0 17670	14 000—21 800	131.000	106 200	1.778
N	"	4	Hose, unlined linen	0 19170	12 590—15 000	178 000	153 000	1.800
D'	"	2	Hose, rubber lined	0 20750	17 000—21 300	157.000	57.200	1 891
V	"	3	Hose, rubber lined, curved	"	17,000—21.300	"		1.816
W	"	3	" " " "	"	17 000—21 300	"		1.858
X	"	3	" " " "	"	17 000—21.300	"		1.803
Y	"	3	" " " "	"	17 000—21 300	"		1 852
Z'	"	3	" " " "	"	17.000—21.300	"		1.816
D''	"	3	Hose, rubber lined, straight	"	17 000—21.300	"		1.873

s made by some of the pioneers in experimental

EXPERIMENTS ON RIVETED PIPE
BY
L. C. GILTNER AND D. A. KETCHUM, JR.

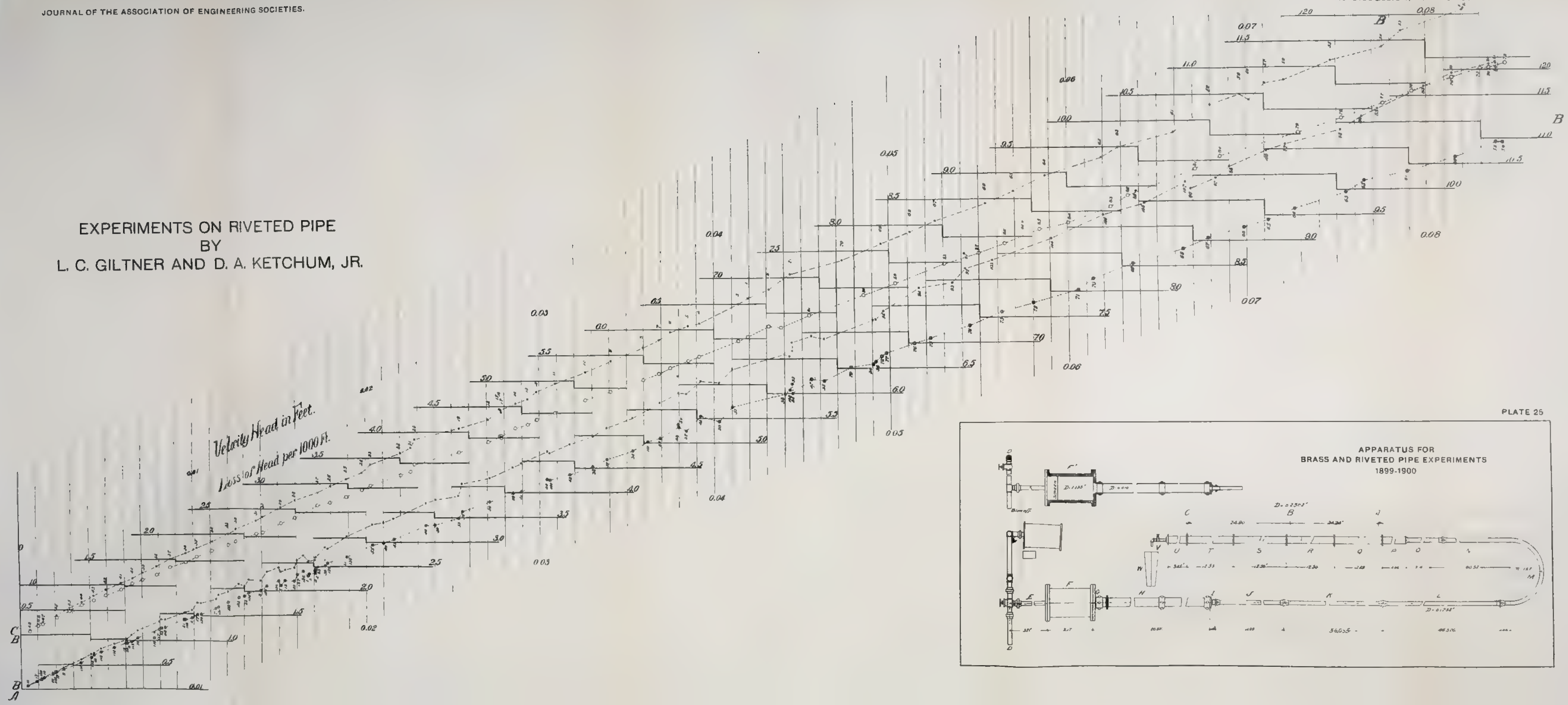


PLATE 25

APPARATUS FOR
BRASS AND RIVETED PIPE EXPERIMENTS
1899-1900

forming irregular orifices within the pipe, brought the value up to 1.98. Again, of two disc meters, otherwise of exactly the same size and type and running under similar conditions, one, which had exceedingly meager, tortuous and rough-edged passages, gave $n = 1.93$, while the other, with much freer passages, gave 1.82.

Experiments were made also with a disc-shaped box, into which the water was led either tangentially or radially, and from which it discharged axially. When the water entered tangentially, a whirl was formed, producing a great difference of pressure between the circumference and the center, owing to centrifugal force, the pressure at the circumference being of course the greater. In this case $n = 2.13$. When the water entered radially, no whirl occurred, the difference in pressure was much less, and $n = 1.83$.

In all these experiments, which were carefully made, n showed a marked tendency to be less for low than for high velocities; and, since an average had to be taken, it was found useless to attempt to give n to more than two places of decimals.

Mr. George H. Fenkell.—The author feels that he can say but little in conclusion.

The discussion by Mr. Hazen is not only very interesting, but is of great practical value, especially to those engineers who are accustomed to use the slide rule in all ordinary computations. As to the formula $V = c^1 r^{0.625} s^{0.50}$, it is probable that none has as yet been advanced which gives any more uniform values for the constant than this.

The following table, No. 7, gives values for the constant in Mr. Hazen's formula, corresponding to various values for the same in the Chezy formula. The numbers in italics in the table are the nearest values of c^1 to 130, the co-efficient used by Mr. Hazen in Table No. 2; and they show, in a general way, the divergence in values of the constants in the formulæ.

The discussion by Mr. Hubbell on some of the uses of logarithmic paper is timely, and, in a general way, coincides with the author's experience. Many of those who have heretofore made use of this valuable instrument in the reductions of various observations seem to have partly, at least, lost sight of its disadvantages, as well as some of its most valuable features, and the reduction of the experiments on 12-inch pipe given by the same writer illustrates several of these points.

It is not necessary for Mr. Williams to apologize for presenting, in his discussion, the results derived from again reducing the observations made by some of the pioneers in experimental

hydraulics. We can never hope to attain perfection in our work, and it is only by careful study of the past that we can hope to improve in the future.

In Fig. 2, Plate 26, Mr. Williams shows that the intercept ± b, as shown on Plates 1 to 20 and in Table 1, "may indicate that H_f does not vary exactly as H_v or V^2." We know that this is true with the smaller sizes of pipes, and it may be that in some cases the author has averaged as straight some that are actually curved.

He has, however, endeavored to avoid this. The experiments on the 3-inch riveted pipe and on 2-inch brass pipe are valuable

TABLE No. 7.

COMPARISON OF CONSTANTS IN CHEZY AND HAZEN'S FORMULÆ.

CHEZY FORMULA—$v = cr^{0.50} s^{0.50}$. HAZEN'S FORMULA (—$v = c^1 r^{0.625} s^{0.50}$.

(c and c^1 Remain Constant for All Values of s.)

Size of Pipe.	c	c^1	c	c^1	c	c^1	c	c^1	c	c^1	c	c^1	c	c^1
2	90	*133.9*	100	148.8	110	163.7	120	178.5	130	193.4	140	208.3	150	223.2
4	"	122.8	"	136.4	"	150.1	"	163.7	"	177.4	"	191.0	"	204.6
6	"	116.7	"	*129.7*	"	142.7	"	155.6	"	168.6	"	181.6	"	194.6
8	"	112.6	"	125.1	"	137.6	"	150.1	"	162.6	"	175.1	"	187.7
10	"	109.5	"	121.6	"	133.8	"	146.0	"	158.2	"	170.3	"	182.5
12	"	107.1	"	118.9	"	*130.8*	"	142.7	"	154.6	"	166.5	"	178.4
16	"	103.1	"	114.7	"	126.2	"	137.7	"	149.1	"	160.6	"	172.1
24	"	98.2	"	109.1	"	120.0	"	*130.9*	"	141.8	"	152.7	"	163.6
30	"	95.4	"	106.1	"	116.7	"	127.3	"	137.9	"	148.5	"	159.1
36	"	93.3	"	103.7	"	114.0	"	124.4	"	134.8	"	145.1	"	155.5
42	"	91.5	"	101.7	"	111.9	"	122.0	"	132.2	"	142.4	"	152.5
48	"	90.0	"	100.0	"	110.0	"	120.0	"	*130.0*	"	140.0	"	150.0
54	"	88.7	"	98.5	"	108.4	"	118.2	"	128.1	"	138.0	"	147.8
60	"	87.5	"	97.3	"	107.0	"	116.7	"	126.4	"	136.2	"	145.9
72	"	85.6	"	95.1	"	104.6	"	114.1	"	123.6	"	133.1	"	142.6

contributions to hydraulic literature, and Table 6, with values of n, arranges the data of previous experiments in small pipes in very convenient form.

The brief discussion by Mr. Trautwine is particularly interesting, inasmuch as it deals with the loss of head usually occurring in meters, a subject apparently much neglected in the past, especially in sizes over one inch.

Probably one reason for this apparent neglect in the past has been the difficulty in measuring accurately the losses of head when velocities are extremely low with any apparatus yet proposed.

SUBMERGED PIPE CROSSINGS OF THE METROPOLITAN WATER BOARD.

By Caleb Mills Saville,* Member of the Boston Society of Civil Engineers.

[Read before the Society, February 20, 1901.†]

In the fall of 1895 the work of laying pipes for the water supply of the district immediately surrounding Boston was begun by the Metropolitan Water Board, two members of this Society, Mr. F. P. Stearns and Mr. Dexter Brackett, having been appointed, respectively, Chief Engineer and Engineer of the Distribution Department. In laying the pipes to the several parts of the district a number of rivers were crossed, and the methods employed in laying the pipes at some of these crossings, while perhaps not presenting any novel features, were of some interest, if for nothing more than their variety.

MYSTIC RIVER CROSSING—36-INCH PIPE.

Of the two 48-inch pipe lines running from Chestnut Hill Reservoir to Spot Pond, the easterly one crosses under the Mystic River, just east of the bridge on Middlesex avenue, between Medford and Somerville. At this point the river is a tidal stream about 1100 feet wide at high water and about 300 feet wide at low water. The average range of the tides is about 10 feet, and at low water there is a depth of about 9 feet in the channel. Rod soundings were made along the line of the proposed location, and it was found that, except near the Somerville shore, where gravel and sand were found, from 10 to 20 feet of river mud overlaid, and imperceptibly blended into, a stratum of sandy silt of unknown depth. The work done at this crossing consisted in laying two parallel lines of 36-inch cast iron pipes 5 feet 9 inches on centers under the river and connecting them by means of Y-branches with the 48-inch pipes previously laid on each shore.

In the early part of March, 1897, the contract for doing this work was awarded to MacRitchie & Nichol, of Chicago, who commenced operations about the middle of April. The first work was the excavation of the trench for the pipes, and this was done by the Eastern Dredging Company. The trench was dug about 35 feet wide at the top, and had an average depth of about 8 feet below the surface of the mud, the lowest point

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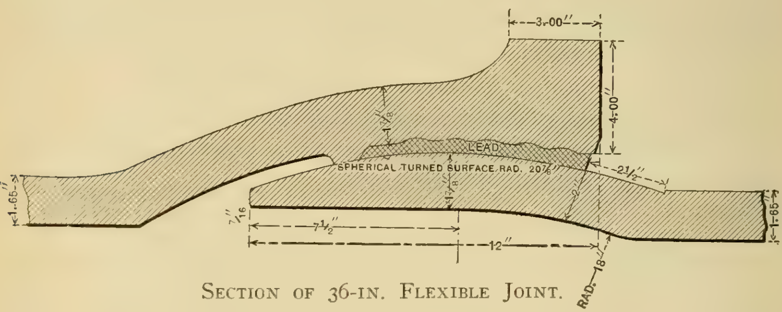
*Division Engineer, Metropolitan Water Board.

†Manuscript received March 16, 1901.—Secretary, Ass'n of Eng. Socs.

dredged being about 16 feet below mean low water. During this work the dredges were kept in line by ranges set upon shore, and the depth was regulated by tide gages and marks on the dredging apparatus and by sounding chains. Three different styles of dredges were used, each suited for the particular place in which it worked. From near the channel to the north shore the bed of the river rose gradually; and, beginning at the channel, a large dipper dredge excavated the material, working against an almost perpendicular face, the material standing well if not left



SECTION OF 36-IN. FLEXIBLE JOINT.

Deflection, 1 in 8.

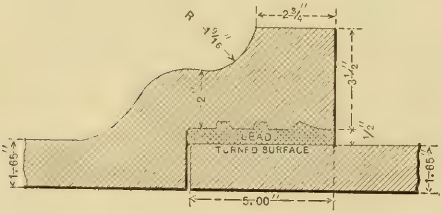


PLATE I. SECTION OF SPECIAL JOINT FOR PUTTING PIPE TOGETHER UNDER WATER.

Spigot turned off and lead cast in bell.

too long. Across the channel, where the bottom was comparatively level, and where, on account of navigation and the opening and closing of the draw, it was necessary to use a dredge more easily handled, an ordinary clam-shell dredge was used. South of the channel and well out of the way of vessels, a dredge having an A frame and long boom on which was a clam-shell bucket was used. From the north shore to the channel the material was loaded into scows, towed about half a mile and dumped on the mud flats, from which it was afterward re-dredged for filling around the pipe. From the channel to the south shore the material was deposited on the mud flats alongside the trench by the scow with the long boom, and later replaced by the same

scow. The work of excavation occupied about forty-four days, during which there were excavated about 11,000 yards of material, an average of about 250 cubic yards, or 27 lineal feet, of completed trench per day. In backfilling, the trench was filled to a point about two feet above the tops of the pipes; 19 days were employed on this work, 500 cubic yards being replaced per day,—equivalent to backfilling about 63 lineal feet of trench. The costs of the excavation and backfilling were respectively 54 cents and 23 cents per cubic yard. On account of the material encountered, it was decided to use a pile foundation for the pipes throughout the entire length of crossing. The piles were of spruce, driven about 23 feet into the river bottom by a floating pile driver having a hammer weighing about 2000 pounds, working with a fall of about 15 feet. The piles were driven 6.3 feet on centers, in two-pile bents, crosswise of the trench, and the bents were spaced 12.1 feet apart and in such position that each pipe, when laid, would have a bearing on a pile bent about four feet back of the face of the bell of the pipe, except at the spherical joints, where an extra bent was driven in order that there might be a support on each side of this joint. The piles were capped with 10 x 10 spruce timber and were cut off and the caps bolted on under water by a diver. The cost of cutting the piles and bolting on the timber was $3 per pile, and the price for furnishing and driving the piles was 12½ cents per gross pile foot.

The pipes under the river below Elevation 5, Boston city base,* were furnished by the contractor after being inspected and accepted by the Metropolitan Water Board. They were 1.65 inches thick and were of five different kinds, as shown in the following table.

	Length, Feet.	Weight, Lbs.	Cost per Ton.	Lead per Joint, Lbs.	Depth of Lead in Joint.
Spherical bell with spherical spigot	12.53	8260	$23.90	248.0	8 ins.
Spherical bell with bead spigot	12.17	8140	23.90	248.0	8 "
Grooved bell with spherical spigot	12.59	8040	23.90	81.5	3 "
Grooved bell with bead spigot	12.10	8210	17.90	81.5	3 "
Grooved bell with taper spigot	10.10	8030	22.90	81.5	3 "
Sleeves	....	....	40.00	128.3	4 "

The spherical joints were similar to the Ward joint, a flexible ball-and-socket joint designed for a maximum deflection of 1 in 10 in any direction without the spigot leaving the bell. In these

*Boston city base is 0.64 feet below mean low water.

joints, however, the lead always remains in the spherical bell, while a raised portion, cast on the spigot end of the next pipe and turned truly spherical, plays against the stationary lead in the pipe bell when the joint is deflected. At the base of this raised portion is a stop, against which the face of the bell is pressed when the maximum deflection of the joint is reached, while in the spherical bell is a raised ring turned to a true circle, which presses tightly against the raised portion cast on the spigot, and prevents lead from running into the pipe when the joint is run. On Plate I are shown sections of the spherical and taper joints, and on Plate II is an elevation of the pipe-laying scow, showing the method of laying the pipes. The scow used was of the ordinary pattern, about 70 feet long and 23 feet wide, with a flush deck. On this deck were erected two stiff-legged derricks for laying the pipe, four winches for moving the scow, a 4-inch centrifugal pump for jetting out the trench if it became filled, an hydraulic pressure pump, furnishing power for pipe laying, an air compresser used in testing for leakage and a boiler furnishing steam to the pumps and the air compressor. On one side of the scow was a straight truss, about 75 feet long, suspended from the derrick in such a manner that a section of pipe fastened to the lower chord of the truss would hang parallel with and just clear of the side of the scow. On the opposite side of the scow was a smaller scow, loaded with gravel, which was fastened to the pipe-laying scow, and which served as a counterweight to balance the pipe on the truss.

The pipes were made up on a temporary wharf, erected for the purpose, not far from the work, usually in sections of six pipes each. At one end of a section was a pipe with a grooved bell and taper spigot, the other pipes being usually of the ordinary pattern. Into the bell end of the last pipe in each section the taper spigot of another pipe was temporarily inserted and the joint run with lead.

When this joint had cooled, this spigot was pulled out, leaving the lead joint in the bell. The pipe with this taper spigot would be the first pipe used in the next section, and when this next section was put in place this spigot would again be fitted into the lead joint from which it had been pulled. After the section was fastened to the truss by chains, the scow would be warped into exact position by means of the winches and anchors. When properly located, the section would be lowered on the truss and placed as directed by a diver. On the end of the truss nearest the pipes already laid was a hydraulic cylinder, to the

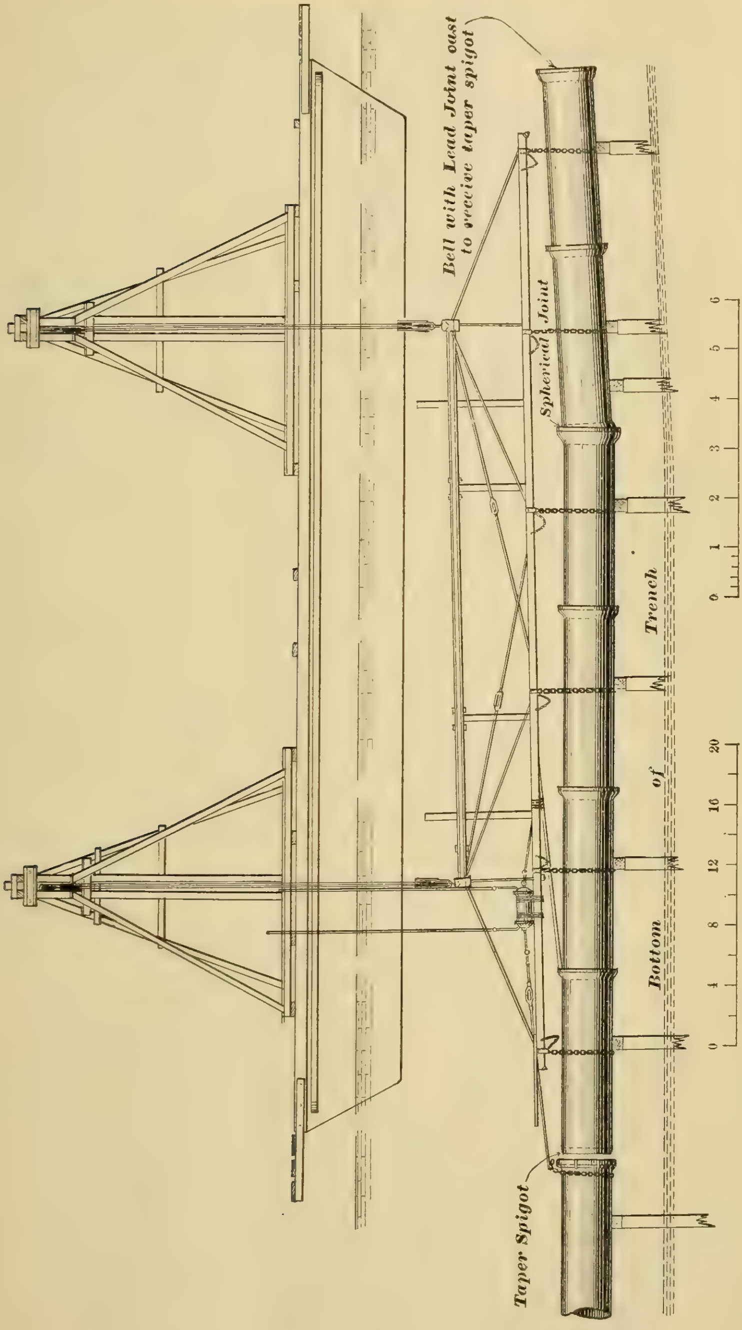


PLATE II. ELEVATION OF PIPE-LAYING SCOW, MYSTIC RIVER, 1897.

piston of which was fastened an iron rod with a hook at the end. A chain having been fastened back of the bell of the last pipe laid, this hook would be fastened into it, and, when oil was forced into the cylinder, the truss would be drawn forward and the spigot of the first pipe attached to it would be forced home into the bell of the last pipe laid. Fastened to the bell was an iron collar which served the double purpose of enabling the diver to more easily enter the spigot, and it also seemed to protect the lead joint in the bell from being forced out of place by the spigot being carelessly entered. Wooden bulkheads were kept in the ends of the pipe sections until just before the spigot was forced home, in order to keep mud and foreign bodies out of the pipe line. Plate 10 shows a section of pipe ready to be lowered.

Across the river the pipes were laid in a straight line horizontally, but where vertical deflections occurred the spherical joints were used. These pipes with their joints were built into the sections, the same as the other pipes, the joint being deflected to fit the position in which it was to be placed. After the pipes were all laid they were thoroughly calked by the diver, and then tested for leakage before the trench was refilled. For use in testing, a 1½-inch hole had been drilled in the top of that pipe of each line that was to be at the lowest point. While being laid, a plug was screwed into this hole, but, when ready for testing, the plug was removed by the diver, a bushing screwed in and a 1-inch wrought iron pipe screwed through the bushing. One end of this pipe was opened and placed about one inch from the bottom of the pipe. On the other end was a check valve, opening outward. Manhole pipes, for allowing access to the interior of the pipe lines, were placed on each line on both sides of the river, and through the covers of these pipes on the Somerville shore holes were drilled and a flexible steam hose laid from the air compressor on the pipe-laying scow moored near by. Air pressure being put on, the water in the pipes was forced out through the check valve on the inch pipe. When the water was all discharged, this pipe was withdrawn, and the plug screwed back by the diver. The 36-inch pipes were then inspected by members of the engineering force, who went through both lines from end to end. After this, air was pumped into the pipes, and a pressure of 25 pounds per square inch maintained for about a week. During this time, several large leaks, that were indicated by the air bubbles, were stopped by the diver calking the lead in the joints. Water was then admitted, and after several trials of air and water pressure a satisfactory pipe line was obtained. The same methods

and pipe-laying plant employed at the Mystic River were also used in laying double 36-inch pipe lines under the Charles River in two places in Cambridge.

The total cost of this work, including pipe, labor, materials and an allowance for the use of the tools and plant, was about $13.25 per lineal foot, of which $6.75 per lineal foot was paid for the pipes.

MALDEN RIVER CROSSING—36-INCH PIPES.

The 48-inch pipe line, a part of which has just been described, also crosses under the Malden River just north of the bridge on Medford street, Malden. At this place the river at high tide is about 120 feet wide and 10 feet deep, while at low water there is only a shallow stream a few feet wide. The material encountered was a thin layer of river mud, overlying a stratum of sand and gravel a few feet thick, under which was a stiff blue clay, which made an excellent foundation on which to lay the pipes, and an ideal cut-off into which to drive the sheet piles of a coffer dam. On the east side of the river was a granite sea wall, and in the center was a wooden draw pier about fifteen feet wide, on a pile foundation. On the west bank, at the beginning of the work, the marsh flats sloped to the water; but later, under a separate contract with the owner of the land, a wooden bulkhead was built by the firm doing the work for the Metropolitan Water Board. As at the Mystic crossing, the work to be done was to lay two lines of 36-inch cast iron pipes under the river, and by Y-branches connect the two lines with the 48-inch pipes previously laid on each side. In this case, and in those following, the pipes were furnished by the Metropolitan Water Board. A contract for doing this work was made with Moore & Co. and W. H. Ward, of Boston, and the work was begun about the middle of October, 1897, and finished February 1, 1898. As there was very little navigation passing this point, especially at this season of the year, the contractors decided to use a coffer dam for laying the pipe. The first work done was to set up three large steam derricks, one on each side of the river and one on the pier about half-way between the other two. These derricks were so arranged that materials could be passed by them from one end of the work to the other. In order to build the coffer dam and lay the pipes, it was necessary to take down portions of the sea wall, bridge and draw pier. In removing the sea wall, it was found to rest on piles, which it was expected could be capped for a platform for supporting the sea wall over the pipe lines. When, however, the attempt was made

to saw these piles off, they fell out of their places, being only about five feet long, and it was necessary to drive new piles for the support of the wall. In taking down the bridge pier it was desirable to remove several oak piles. Two attempts were made to draw them; one by means of a chain attached to the piles and to the end of the derrick boom, and the second by means of a long timber used as a lever, the long end of which was likewise attached to the boom. Although a force estimated at about twelve tons was exerted, neither method was successful, and the piles were sawed off. The walls of the coffer dam were composed of a single thickness of 6-inch spruce and 4-inch yellow pine timber, supported by spruce piles and 8 x 12 spruce waling, tied together and braced as shown on Plate III. The sheeting had grooves, into which hard pine splines 1 inch thick and 2 inches wide were placed. This sheeting was about 24 feet long, and was driven by an ordinary land pile-driving machine into the clay about two feet below the bottom of the proposed pipe. In driving, the sheeting was kept close up to that already driven by an iron dog and an oak wedge which was tapped with a maul from time to time as it loosened under the driving. For the support of the pile driver, a few spruce piles were driven out in the river by means of the pile-driving machine erected on a raft made of oil barrels and large timbers. On these piles and the bridge a scaffolding was placed, and on this the pile driver worked while driving the sheet piles in the coffer dam. Between the walings, the coffer dam was 14 feet 6 inches wide, and was built in two sections, each extending to the middle of the river, and one removed before the other was built. The first section was about 85 feet long, and at its river end two cross walls about eight feet apart were built. When the rest of this section was removed, these walls and the longitudinal walls connecting them were not removed, but became the river end of the second section. In each of these cut-off walls a gate was built, so that the dam could be flooded if necessary. The coffer dam was comparatively tight, but to avoid straining it was customary to open the gate and flood the dam when the tide had risen to within two or three feet of the top. When the tide fell, the gate being open, the water would fall inside the dam to the bottom of the gate and the remainder would be pumped out by a 6-inch centrifugal pump. About two hours was necessary to free the dam from the water. In removing the coffer dam, an attempt was made to draw the sheeting for use in the other portions, but after

several attempts had been made without success, it was cut off about one foot below the top of the pipes. In removing the round piles, they were first sawed off as low as possible and a $1\frac{1}{2}$-inch hole bored down into the pile four or five feet. A dynamite cartridge was then pushed to the bottom of the hole and exploded by a battery on shore, and the pile would be broken off as low down as the cartridge was placed. Across the river the pipe was laid with its top about five feet below the river bed. The pipes used were about 1.65 inches thick; the lead space in the joint was about five inches deep and took about 150 pounds of lead when run solid. In laying the pipes, work was begun in the center of the river and the pipes laid up each side. The spigot end of the first pipe to be laid was put through a circular hole in the inner of the two cut-off walls mentioned above, and the space between the plank and the pipe calked tightly, to prevent water coming in when this inner wall became the outside wall of the next section. When the next section was ready, a sleeve was put on this spigot end and then the pipes were laid up the bank. On account of the cold weather and the large amount of lead to be poured into a joint, it was found expedient to run the joint at two pourings,—one from the sides and the other on top. A clay roll was used long enough to go completely around the pipe and make sufficient gate at the top. For the first pouring this roll would be brought two-thirds the way round the pipe and lead poured into the joint from each side of the pipe up to this point; the ends of the roll would then be brought over the top of the pipe and the remainder of the joint poured in the ordinary manner. These joints were perfectly satisfactory, and when the pipe was tested it showed no leakage whatever. The excavation, backfilling, pipe-laying and handling timber and machinery were done by the derricks, and on this account only a minimum number of men were employed. The estimated cost of building the coffer dam was about $13 per lineal foot.

MYSTIC RIVER CROSSING—20-INCH PIPE.

As a part of the main pipe line supplying the town of Arlington with water, a 20-inch pipe was laid under Mystic River just north of the bridge on High street, Medford, which is also just below the lower of the two Mystic Lakes. For this crossing a pipe 1 inch thick and weighing about 2700 pounds per 12-foot length was used. This pipe was of the ordinary bell-and-spigot type, but made extra thick to provide for deterioration from rust, etc.

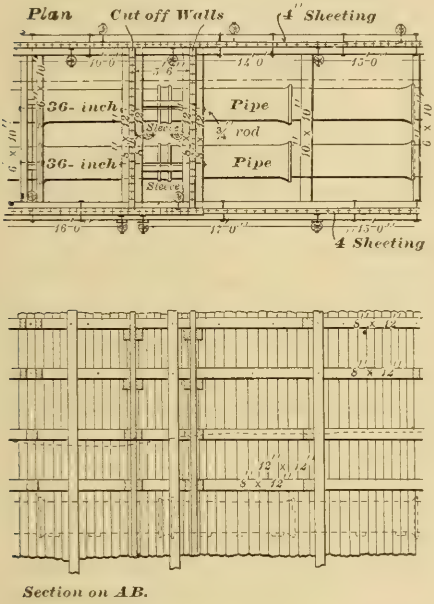
The location of the pipe crossing is 60 feet north of the bridge, the river being here about 35 feet wide and having a maximum depth of $3\frac{1}{2}$ feet. The top of the pipes were laid one foot below the bottom of the river bed at its lowest point. On the east side the ground slopes gradually to the water, while on the west bank there is a rough retaining wall about $1\frac{1}{2}$ feet high. The work of making this crossing was included in the pipe-laying contract of Bruno & Salomone, of Boston, and was begun about the 1st of June, 1899, on the east bank of the river.

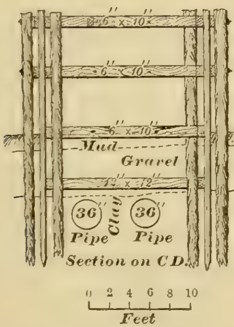
A section of coffer dam 5 feet wide inside, starting about fifteen feet back from the edge of the stream, was built about thirty feet out into the river and securely bulkheaded. The sheeting used on this section was ordinary spruce plank 2 inches thick and about 8 feet long, driven about one foot below the bottom of the trench. The material taken from this trench was sandy clay and was banked about outside of the sheeting. Very little water came in through this material, one hand pump easily keeping the trench dry. Three pipes were laid in this trench and a bulkhead built just back of the last bell. When this work was done, pairs of 4 x 4-inch stakes about 5 feet long were driven on each side of the line of the proposed trench at intervals of about ten feet across the river. These stakes were thoroughly secured to each other by 2-inch planks, spiked between them both with and across the current. On this foundation was placed a platform for supporting the derricks, pumps, etc. Later, other 2-inch planks were spiked to the posts crossways of the river and fastened to them as far down in the water as was possible. These planks helped to confine the gravel and clay that was packed around outside the sheeted trench.

About ten or twelve feet on each side of the line of the trench, and also across the end about two feet beyond where it was intended to stop this section, a dam of sand bags was built. The bags used were 50-pound coffee bags filled with sand, and were laid three or four tiers high.

After this portion of the work was finished, 3-inch tongued-and-grooved planks, about 8 feet long, were driven in two parallel lines about five feet apart, and the material excavated was thrown around the outside of the sheeting, between it and the sand bag dam previously built. In the bottom of the trench the material was found to be gravelly, but one hand pump was sufficient to handle the water. When the pipes were laid in this section, a bulkhead similar to that used in the preceding section was built. These bulkheads served as the rear end of the trench

when a new section was opened, and allowed the bell end of the pipe already laid to project into the new section of trench. After the pipe was laid and backfilled, the sheeting was pulled, and the sand bags in the side walls were taken up and moved ahead





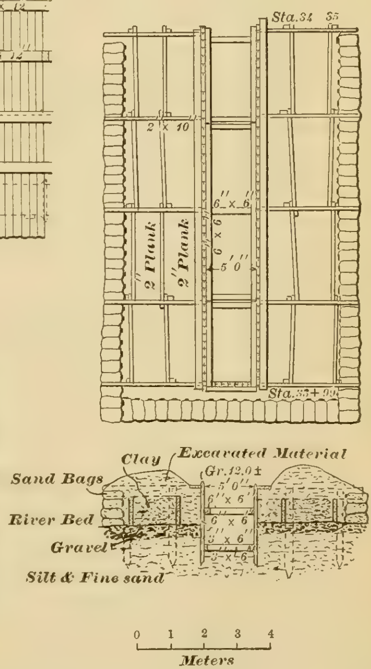


PLATE III. PLAN AND SECTIONS OF COFFER DAM, MALDEN RIVER, 1898.

PLATE IV. PLAN AND SECTIONS OF COFFER DAM, MYSTIC RIVER, 1899.

to form the walls of the next section, which extended from about the center of the river to the west bank and completed the crossing. The sand bags in the end were also taken up and moved back into the stream till they were just back of the bulkheaded portion of the pipe, and when the same process of filling with clay

and driving the sheeting had been finished, this portion of the pipe was inside the coffer dam. Less care was taken with this section, and three hand pumps were necessary to take care of the water. Plate IV shows a plan and sections of the coffer dams. The total cost of the work was estimated to be about $7 per lineal foot.

SAUGUS RIVER CROSSING—20-INCH PIPE.

Nahant and Swampscott having, in 1898, applied for permission to enter the Metropolitan Water District, it became necessary to lay a main for their supply. On the line of this main it was necessary to cross the Saugus River on Broadway at the Fox Hill bridge, between Lynn and Saugus.

The Saugus River at this point is a tidal stream varying in width from about 500 feet at high water to about 250 feet at low water, the average rise and fall of the tides being about 10 feet, and there being a maximum depth of about 5 feet in the channel at low water. From rod soundings it was found that the bed of the river was composed of a stratum of river mud varying in depth from 4 to 10 feet and overlying a stratum of silt containing more or less coarse sand. Three plans were somewhat considered for crossing this river: one to lay an entirely submerged line, another to lay the pipe wholly above water in a box attached to the bridge and the third a combination of the other two. The principal objection to the first was the expense, especially as it seemed likely that a pile foundation would be necessary the whole distance. To the second plan the objection was that, although the existing draw was very narrow and had not been used for a long time, yet, on account of certain wharf privileges further up, it would have been difficult, without considerable expense, to obtain permission to permanently close it to navigation. The third method was adopted, and it was decided to carry the pipe inclosed in a box on the bridge as far as the channel and to cross this by an inverted siphon similar to those in use at several of the river crossings in Boston and described by Mr. Brackett in a paper before this Society published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for February, 1886. This siphon consisted of a cast iron pipe surrounded with concrete and boxed with heavy timbers thoroughly bolted together. The shape of this siphon was like three sides of a parallelogram, the middle side resting on the bottom of the river about twelve feet below Boston city base and the two other sides standing one on each side of the channel forty-five feet apart.

About the time it was intended to lay this pipe, the Lynn and Boston Street Railway Company decided to widen the existing bridge and so obtain a portion that could be used exclusively by them. Arrangements were made with the railroad company and their plans modified to the extent of driving extra piles west of the bridge in all the pile bents and extending their girder caps about six feet. On the foundation thus formed was placed the pipe box afterward built.

In the last part of March, 1899, the contract for building the pipe boxes and siphon was awarded to W. H. Ryan & Co., of East Boston, and the work of getting ready the materials was at once begun.

The siphon box was framed and fitted at a lumber yard at East Boston, then partially taken apart, loaded onto a lighter and carried to the site of the proposed work. The box was built of first quality hard pine lumber, bolted and strapped together. The dimensions of the lumber and detail of the bolting is shown on the plan and elevation on Plate V. A trench was dredged across the channel to receive the bottom portion of the siphon, and two of the four guard piles about each of the upright portions were driven to serve as guides in lowering the box.

In the dredged trench two bents of two spruce piles each were driven and cut off as far down as possible at low water. These piles were capped with 14 x 14-inch hard pine riders at right angles to the trench, the caps being held in place with iron dogs. At high water the bottom portion of the box was floated into place directly over the pile caps, and at low water it was allowed to settle down upon them, where it was securely held from again floating by cross-braces bolted to the surrounding piles. The outer and two side pieces of the vertical portions were then bolted into place during succeeding low water periods, while at high water work was done on the pipe box on the bridge. Before placing the inner sides of the vertical portions and the top of the horizontal part, the pipe was laid by the Maintenance Force of the Water Board. As there was only 2 feet and 8 inches clearance inside the box, which was not sufficient to properly calk the joints after the pipe was put in, the pipe for the bottom portion, including the two 20-inch one-quarter curves, was made up and bolted together with 1½-inch steel rods and turn buckles, the pipe resting on cross timbers which in turn rested on the side walls of the box, so that the pipe was directly over its proposed position. When the joints had been made up and calked, the pipe was raised by four pipe jacks, the cross-timbers taken out and the

pipe lowered into its place in the box. After lowering, the joints were carefully examined, and, no movement being apparent, Portland cement concrete in the proportion of 1-2-4 and mixed rather wet was put all around the pipe up to the top of the side timbers, and the top was then bolted on.

The vertical pipes were readily placed in position, as all the inside timbers and the outside key pieces were left out in order to give room for the pipe work. After one pipe had been placed in the uprights on each side, the timbers were bolted on and the space between the pipe and box was filled with concrete, thoroughly rammed with a long stick. The upper pipes in the verticals were not laid until the siphon had been lowered, and then at low water the bells of the pipes already laid were out of water. The vertical portions were tied together with $1\frac{1}{2}$-inch rods, which were held in place by templates while the concrete was being put in.

For lowering the siphon, several methods were suggested,—one, that professional riggers be employed and lower it by means of shears erected on the bridge; another, that two lighters be used, which, being lashed to the siphon at high water, would allow it to settle into place with the fall of the tide. Either of these methods was feasible, but the following method was employed and was much the cheapest and in many respects the most satisfactory. A building mover having been engaged, the four guard piles which had now been driven about the vertical portions were cut off level with the tops of the girder caps in the bridge. Two 14 x 14 hard pine timbers were placed, one on each side of the upright portions; on these timbers a crib work of blocking, such as is used in house moving, was built around the upright parts of the siphon to a point about two feet below their tops. The method employed in lowering the siphon is shown on Plate IX.

At the top, four heavy timbers were tightly clamped to the verticals by means of $\frac{1}{2}$-inch iron rods, and just above these clamps holes were bored in the timbers and iron plugs, 2 inches in diameter, were driven in. Under the clamps, and resting upon the blocking, building movers' jack-screws were placed. At first eight were used to each vertical, but later six were found to be enough. When all was ready, the screws were tightened just enough to raise the siphon box clear of the pile caps on which it rested; these caps were then removed and the work of lowering the box was begun. This work was continued without accident

until the box rested on the bottom of the trench dredged to receive it. The total time employed in lowering the siphon from the time the first block was placed until the last was removed was

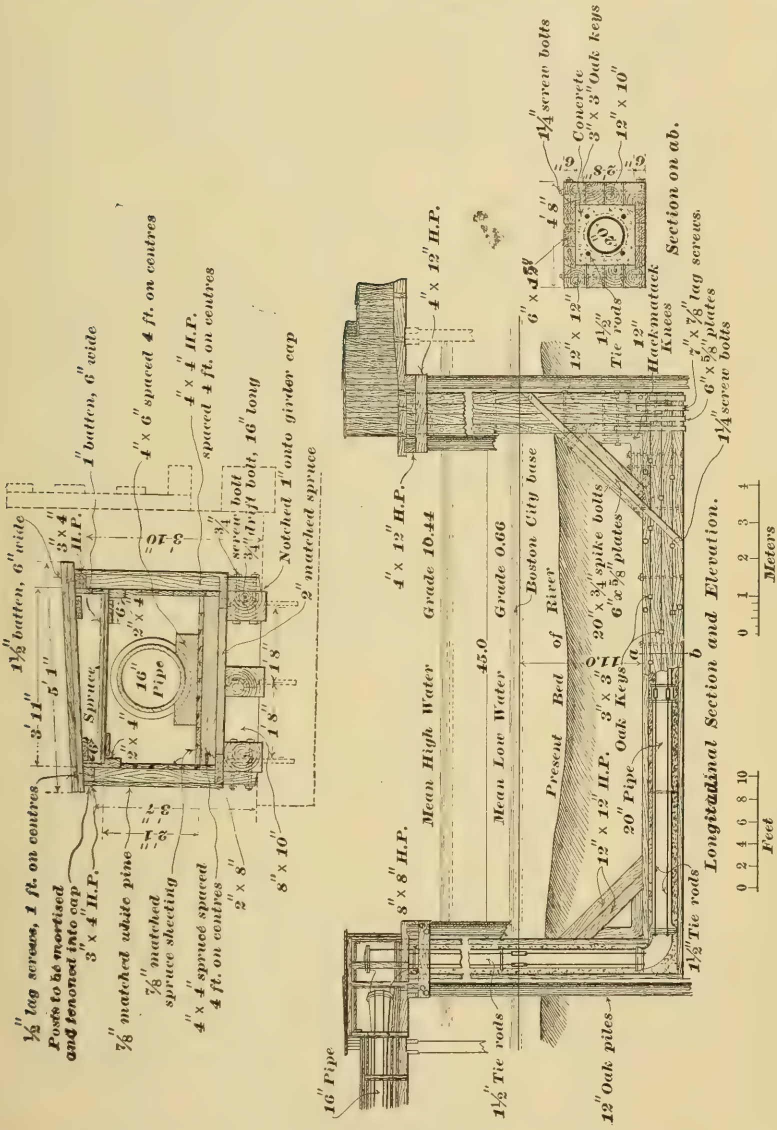


PLATE V. ELEVATION AND SECTIONS OF SIPHON AND PIPE BOX, SAUGUS RIVER, 1890.

three and a half days, and the siphon was lowered at the rate of about one foot per hour during the time the jacks were in use. The total weight resting on the jacks, when the siphon was first raised to take out the pile caps under it, was about 67 tons.

After standing for about two hours, levels were taken on the uprights, and the next day, when levels were again taken, it was found that there had been a settlement of about 0.15 feet. After this no further settlement was noticed, although levels were taken from time to time for about a month.

After lowering the siphon, a fender guard was built around the exposed ends and portions of the old pier which it was necessary to remove were rebuilt. Crossing the bridge and resting on the foundation previously spoken of, the pipes are carried in a double wooden frost box (shown on Plate V), the outer box being of white pine sheething about 4 feet and 9 inches by 3 feet and 6 inches, and the inner box being of spruce 3 feet and 9 inches wide and 2 feet high. The tops of these boxes are in short sections fastened down with lag screws, and if necessary the pipe for its entire length in the box could readily be exposed. This box was about 470 feet long. After the bottom and sides were in place, the pipes were laid by the Maintenance Department, the pipes being first delivered onto a lighter and by it hoisted into place. The estimated cost of the pipe box was $4.40 per lineal foot, or $46 per M. B. M. for lumber used. The cost of the siphon, exclusive of pipe laying and concrete, was $18.50 per lineal foot, or $112 per M. B. M. for lumber used. The concrete cost $7 per cubic yard in place, and the cost of the pipe laying, everything included, was $3.20 per lineal foot.

CHARLES RIVER CROSSING—20-INCH PIPE.

For the supply of Watertown and Belmont, it was necessary to lay a 20-inch pipe across the Charles River at a point nearly opposite St. James street, in Newton, and Irving street, in Watertown.

The river at this point is a tidal stream about 315 feet wide and varying in depth from 2 to 6 feet, depending on the height of the tide and the discharge from the mills further up the river. The work at this river crossing was included in a pipe-laying contract awarded to E. W. Everson & Co., of Providence, and this part of the work was begun June 21 and finished August 27, 1898. The material encountered in the river bed was a gravelly clay, in places very hard to excavate, but allowing very little water to percolate through it into the trench. The trench was dug about 5 feet wide at the bottom and 25 feet wide at the top. For the greater part of the way the average depth of the trench was 8 feet below the river bottom; but for a distance of about 100 feet it was 11 feet deep, in order to

provide for a proposed channel. The excavation was almost wholly done by a steam excavator which was designed and used for the excavation of pipe trenches on land. This machine consisted of a double-drum hoisting engine mounted on a platform, which also carried a boom derrick on a turntable. This machine rested on four flanged wheels, which in turn rested on T-rails. By means of "dead men" and ropes attached to the engine drums this machine could be drawn forward or backward on the rails. Attached to the boom of the derrick was a bucket similar to that used on a dipper dredge, and by means of wire ropes and an anchor this bucket could be pulled some distance from the engine, dropped into the trench, and when pulled back by other ropes the bucket would be filled with the material in the bottom of the trench. When the engine was reached, the bucket would be hoisted up the derrick, turned to the side and the material in the bucket dumped alongside the trench. Except at very high water this machine could work at any time. A portion of the trench about 50 feet long was usually excavated and the material piled about the sides, forming a dam, the top of which was about four feet higher than the river bed. At high tide the water would flow over the top of this dam, filling the trench, but when the tide fell below the top of the embankment a 6-inch centrifugal pump would rapidly clear the trench of water and the pipes would be laid and calked while the water was down. The backfilling was done by men with shovels. No especial difficulty was encountered in laying the pipes, and the plan employed was excellent except that the machine was designed in the first place to excavate less compact material; and many delays occurred in making repairs and adapting portions of the machine to the work, and for this reason the cost was greatly increased. The cost of excavation and backfill was about $7 per lineal foot. The cost of the pipe laying, excluding the cost of the pipe, was $0.80 per lineal foot.

CHELSEA CREEK CROSSING—24-INCH PIPE.

Up to the summer of 1900 the water supply of East Boston had been obtained through two cast iron pipe lines laid under Chelsea Creek from a point on Marginal street, Chelsea, near the Magee Furnace Company's foundry to a point near the junction of Condor and Brooks streets, East Boston.

Chelsea Creek at this point is a tidal stream about 1450 feet wide at high water and about 600 feet wide at low water; the range of the tides is about 10 feet, and when the tide is out there is a maximum depth of about 25 feet of water in the channel.

On account of the depth of water, there is considerable traffic on the stream at all stages of the tide to and from the numerous iron foundries and coal and oil wharves. One of the existing pipe lines was 20 inches in diameter and was laid about 1850; the other line was 24 inches in diameter and laid in 1871. The former line was so badly tuberculated and corroded that it had been practically out of commission for the past few years, and existed only as an emergency line in case of accident to the other. The Boston Water Department had intended to relay this line and had bought the pipes, but before the work of laying them was begun both lines were taken by the Metropolitan Water Board, and the work was done under its direction, the pipes being brought from the city of Boston. In the paper by Mr. Brackett, mentioned above, sketches of the flexible joints used on both lines are shown and a description is given of them. Concerning the method of laying the older pipe, Mr. Brackett says: "This pipe was prepared on a staging and lowered by tackle into the trench, which was then filled with gravel and clay." After the trench was dredged for the new pipe line, the diver encountered a number of piles at various places across the channel, which probably were portions of this staging, and when the old pipes were removed, nearly all the flexible castings had a rope sling about them.

Previous to letting the contract for the pipe laying, both lines of pipe were located as well as possible by rod soundings. These soundings were taken, from a raft anchored in the stream, by men using a rod made up of 15-foot lengths of $\frac{3}{4}$-inch gas pipe coupled together. The soundings were located by angle and stadia distance from a point on a platform built on one of the fender guards near by. On account of the depth of water and the strength of the current and the peculiar manner in which the pipes were laid, much difficulty was experienced in locating the pipe, and at times it seemed as if the bottom of the river might be covered with pipes. However, after repeated soundings, a line was at last determined upon, where the pipe at any rate ought to be located, and later, when the pipe was removed, it actually was found very nearly as expected. Early in August, 1900, the contract for removing the existing 20-inch pipes, laying the new line of 24-inch pipes and rebuilding the pile fender guards and dolphins, which were badly decayed, was awarded to Messrs. MacRitchie & Nichol, of Chicago, the same firm that had successfully laid the submerged pipes at the Mystic and Charles River crossings.

For about 200 feet on the Chelsea side and for about 750 feet on the East Boston side of the channel the existing pipes rested on a pile foundation, raised only a very little above the surface of the mud flats, and were wholly exposed and unpro-

PLATE VI. SCOW RAISING OLD 20-IN. PIPE.

tected at low water. These pipes were of the ordinary bell-and-spigot type, but only 9 feet long. Originally the walls of the pipes had been seven-eighths of an inch in thickness, as was shown by the measurement of the spigot end of a pipe which was pulled out of the bell on the next pipe to it. Beside the

fact that the whole barrel of these pipes was somewhat reduced in thickness, there were also many places where the rim had become softened and could be cut into for a quarter of an inch with a knife. After removal, both the pipes above low water, as well as those below, were found to be very badly tuberculated, the inside diameter of the pipes being reduced as much as two inches with a solid mass of incrustation. Below low water the pipes were laid with a peculiar swivel joint, which was so designed that it allowed the freest possible motion vertically, but allowed no deflection horizontally. These pipes and specials were all connected together with flanged joints. The straight pipes were 9 feet in length and at the end of each three pipe section one of these joints was used, making a right-angled offset in the pipe line.

These pipes were $1\frac{3}{4}$ inches thick, and when covered with clay the iron was excellently preserved. After the pipes were uncovered by a dredge they were lifted from the bottom in short sections by the shears and tackle on a large wrecking scow and taken away, becoming the property of the contractor. The method of raising is shown on Plate VI, where a section with one of the flexible joints is being hoisted. Above low water the pipes were broken by sledges into two-pipe sections and raised by the scow afterward employed in laying the 24-inch pipes. The pipes relaid above low water were 0.95 inches thick, having ordinary bell-and-spigot joints, and the iron of which they were made was of a special composition which it was expected would resist corrosion to a considerable extent. Below low water the pipes were 1.25 inches thick and had ball-and-socket joints similar to those used at the Mystic and Charles River crossings, and described above. In laying the pipes, both above and below low water, a large scow about 75 feet long and 25 feet wide, with a flush deck, was used. The scow was hired by the contractors, who themselves fitted it out with winches, derricks and slide for lowering the pipe. Winches were employed to move the scow by means of anchor lines. For lowering the pipe two stiff-legged derricks and a curved slide were used for the pipe laid below low water, while for that laid above low water only the derricks were used. The slide or cradle by means of which the pipes were laid below low water was about 75 feet long and built curved in shape to an 80-foot radius, which was a little less than the maximum deflection to which the pipes could be laid. This slide was well braced and trussed and hung by wire ropes from the larger of the two derricks, the other derrick being used to raise or lower the tail end

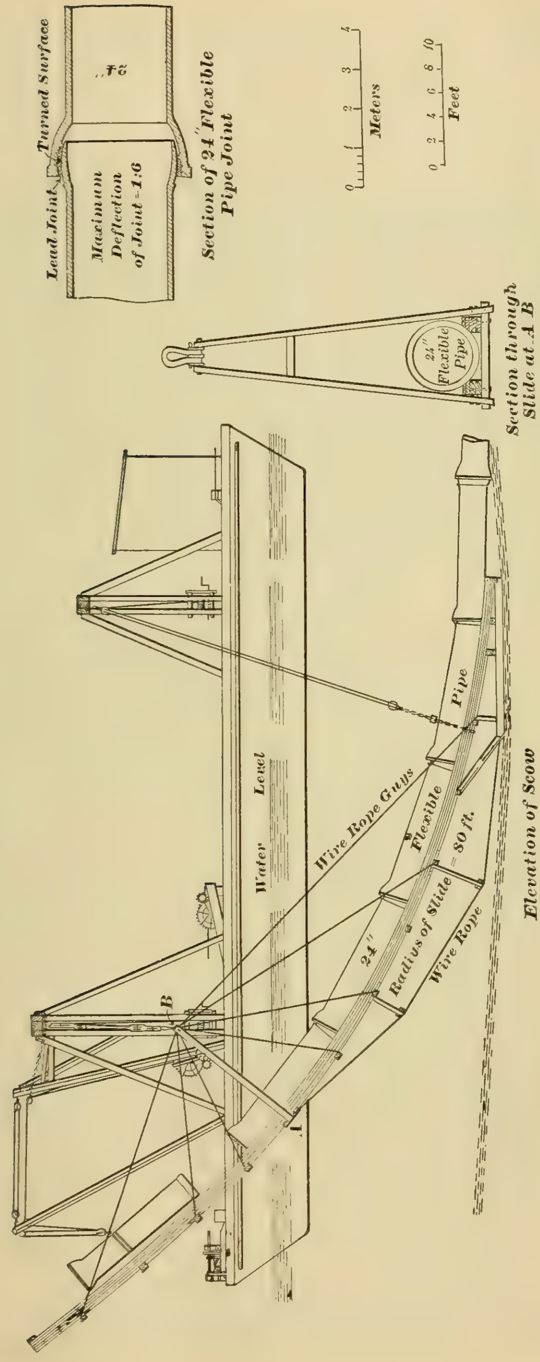


PLATE VII. ELEVATION AND SECTIONS OF PIPE-LAYING SCOW, CHELSEA CREEK, 1900.

of the slide, so that it might at all times be tangent to the bottom of the dredged trench. The tackle was so arranged that the whole slide could be raised or lowered vertically or tipped at any angle in a vertical plane. On the tail end of the slide was a wooden shoe, about 4 feet long, for the purpose of making the slide rest more evenly on the bottom; this shoe also probably served to even off small irregularities along the bottom of the trench. An elevation of this scow is shown in Plate VII. In the first place, this slide was filled with pipes, the joints of which were leaded. The scow was then worked into proper position at high tide, and the tail end of the slide was tilted down until it rested on the bottom of the river, but at such a depth that the end of the pipe would be exposed at low water. This end of the pipe was then securely anchored and the scow pulled ahead about twelve feet, causing the pipe to be pulled down the slide. Another pipe was then placed in the slide by a small boom derrick and the process repeated until all these pipes had been placed in the cradle and slid down into the trench dredged across the channel. This work is shown on Plate VIII. During the work the pipes were stored on a large lighter moored a short distance away, while for the immediate work ten or twelve pipes were stored on the pipe-laying scow and a smaller scow that served as a tender. The laying of the fifty-four pieces of submerged pipe actually occupied two weeks. Above low water the pipes were laid on the same pile foundation as had supported the previous pipe line; the piles were thoroughly examined, and, although they had been in use such a long time, they were found to be perfectly sound below the mud line, and only a little decayed on the outsides of the piles for the portion above the mud. In laying this portion of the pipe line the pipes were usually made up in four-pipe sections on the scow, which was floated approximately into position at high water and the pipe lowered onto the pile caps. At low water these sections were pulled together with tackle and falls and the joint between them leaded. After the pipes were all laid, the joints both above and below low water were thoroughly calked. When completed, the pipe line was subjected to a hydrostatic test of eight-four pounds per square inch for sixty minutes and the leakage recorded by the flow through a $\frac{3}{4}$-inch meter was barely perceptible. For dredging and lining the pipe, ranges were set up on each shore, and by means of the quarter lines, the scows were easily kept in line. For stationing and location, ranges were set on the Meridian street bridge, which was about 1000 feet away and about parallel

with the work. These ranges were so placed that lines drawn through them and a prominent church spire in Charleston would intersect stations on the pipe line. To distinguish the station, large squares of white canvas, with solid black figures about a foot high, were nailed under each of the ranges. For keep-

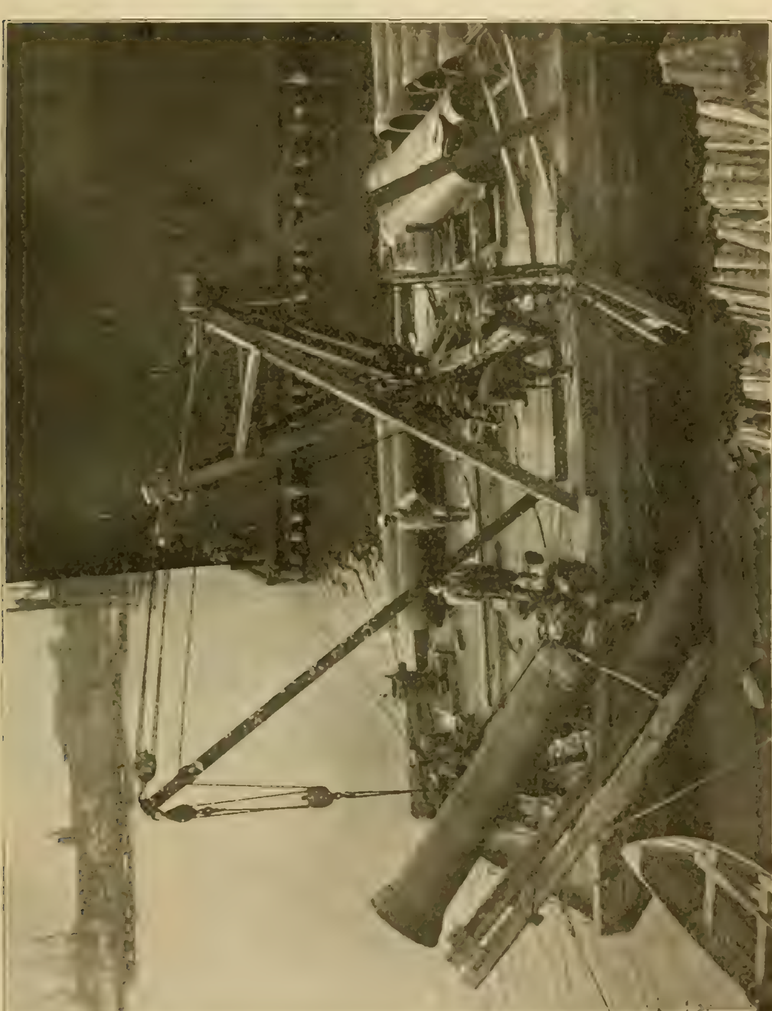


PLATE VIII. SCOW LAYING 24-IN. PIPE, CHELSEA CREEK.

ing the slide from which the pipe was laid in proper position in relation to the bottom of the trench, a profile of the trench was drawn on paper and a paper model of the slide cut out to the same scale as that to which the profile was drawn. Knowing the depth of the water at any station from elevation of

the tide, read from tide gages located near by, the bottom of the slide could be readily adjusted and kept tangent to the bottom of the river by placing it in similar position to that of the model. In the spherical joints 130 pounds of lead per joint was used, while the ordinary joints took about 53 pounds. Of the lead used, about two tons was recovered from the joints in the old 20-inch line.

The cost of this work per lineal foot, estimated from the force accounts kept by the inspector, was:—

For removing the existing pipe and laying the pipe with spherical joints, $8.25, and for removing and laying the pipe with ordinary joints above low water, $2.25. These figures do not include the cost of the pipe, nor do they take into account anything which may have been received for the old pipe. A rental value for the use of the plant is included, and the cost of the dredging was estimated from a rental value of the dredges.

The costs which have been given above for the several river crossings are the actual costs to the contractors doing the work, estimated from notes and force accounts kept by the inspectors on the work. In giving these costs, it has seemed that the cost per lineal foot would be of as much value as a more detailed statement. While there is every reason to believe that the figures are very near the actual cost, yet this work itself is of such special nature that the same conditions under which it was done might never again be encountered, and other conditions would probably modify the cost so that the detailed figures could only be used by one thoroughly familiar with the circumstances under which the figures were obtained.

It may also be said that the actual cost of any engineering work which has been successfully completed without accident should only be used as a basis for estimating similar work.

Experience and judgment should dictate allowances to be made for unexpected conditions or mishaps.

DISCUSSION.

Mr. Clemens Herschel (by letter).—To the description of the several methods of laying water pipe under and across rivers given by Mr. Saville, it seems fitting to add another, showing a method devised and used by the writer five years ago to convey water across the Passaic River at Belleville, N. J. At this point the Passaic River is a tidal stream, with a mud bottom, mud flats or wharves on either side, about 600 feet wide between highwater lines, some 15 feet deep, and about 4 feet of tide and considerable

navigation on the river daily. The problem was to connect two 42-inch steel pipes, carrying some 40,000,000 gallons daily under some 350-foot head at the river, and it seemed to the writer that no form of flexible joint would answer the purpose; for the reason that such joints, even when well made and water-tight at the outset, would, under the pressure named, soon wear or cut out and cause an undue loss of water by leakage. At such high pressures lead will cut out under the action of even very minute jets of water, like a softer substance would under the effect of streams at ordinary pressures, and any effect of that sort will proceed more and more

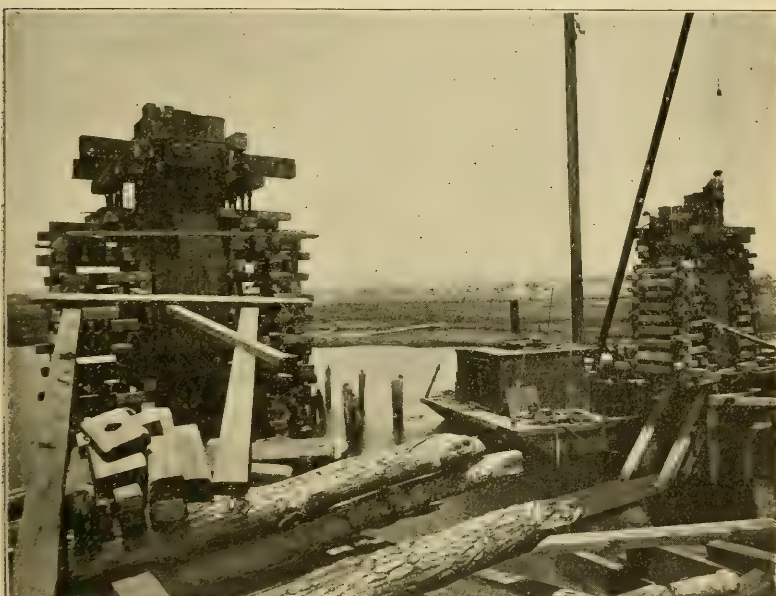


PLATE IX. LOWERING 20-IN. SIPHON BOX, SAUGUS RIVER.

rapidly as the escaping streams enlarge and as time goes on. It seemed to the writer that this consideration and the locality named positively excluded all forms of leaded joint.

Instead, he was led to reflect that while the ordinary screw-joint may be called a stiff joint, yet a pipe line 600 or more feet long, when made up of 20-foot lengths with screw joints, would have considerable flexibility. A piece of bamboo two or three inches long is a very stiff thing when observed by our gross senses, but the same bamboo twenty feet long can be bent into a circle without breaking and with perfect ease. Similarly, a four-

foot riveted steel pipe is a rigid structure, in the ordinary sense of the term, but a line of it 500 feet long will readily bend to a circle of 1500 feet radius, and, what is very important, without even starting leaks in it. I have seen such a pipe (500 or 600 feet in length) float out of the trench it had been laid in, arrange itself in graceful reversed curves on the surface of the ground, and yet be apparently none the worse for its adventure after it had again been forced back into the original ditch.

Most pipe lines would float in water, and to remain on the bottom, while empty, would have to be loaded.

The plan adopted was, therefore, upon these considerations, to lay seven parallel lines of 18-inch lap-welded steel pipes, with screw joints, and loaded by cast iron reinforcements at each joint, by means of dragging the pipe line across the bottom of the river in a trench dredged for the purpose, and this was successfully done without the slightest mishap except unimportant ones during the first attempts on the first of the seven lines. The seven lines have been in use now about five years and have never leaked. I know this, because there is a Venturi meter on each side of the river, both of which are read and compared daily.

The pipe lines were put together on one shore in 200-foot sections; that is to say, 200 feet of pipe was put together, a temporary cap was placed at the two ends, and while keeping the pipe full of compressed air (to detect leaks) the 200-foot length was hauled out into the river by an ordinary hoisting engine set up on the opposite shore. The loading of the pipe having been so proportioned that there was only a slight excess of weight over the power of flotation, this hauling over was really a very simple matter. The first 200 feet once hauled out into or under the river, the inshore cap could be taken off, another 200 feet joined on, the cap be now replaced and the process first above described could be repeated, and again repeated, until the end first launched appeared above water on the opposite shore.

So satisfactory was the plan pursued that, were I to repeat it, I should not hesitate an instant to haul across one 42-inch riveted pipe in the manner described, rather than seven lines of 18-inch pipe. At moment of writing, this plan of operation has been adopted for laying a 6-foot steel, riveted pipe across a tidal stream. In this case the pipe must be braced on the inside to withstand the water pressure tending to collapse the pipe, but this bracing will form the load needed to keep the pipe on the bottom until it is laid from shore to shore. In this, and in every case of hauling pipes or tubes in the manner here described, the

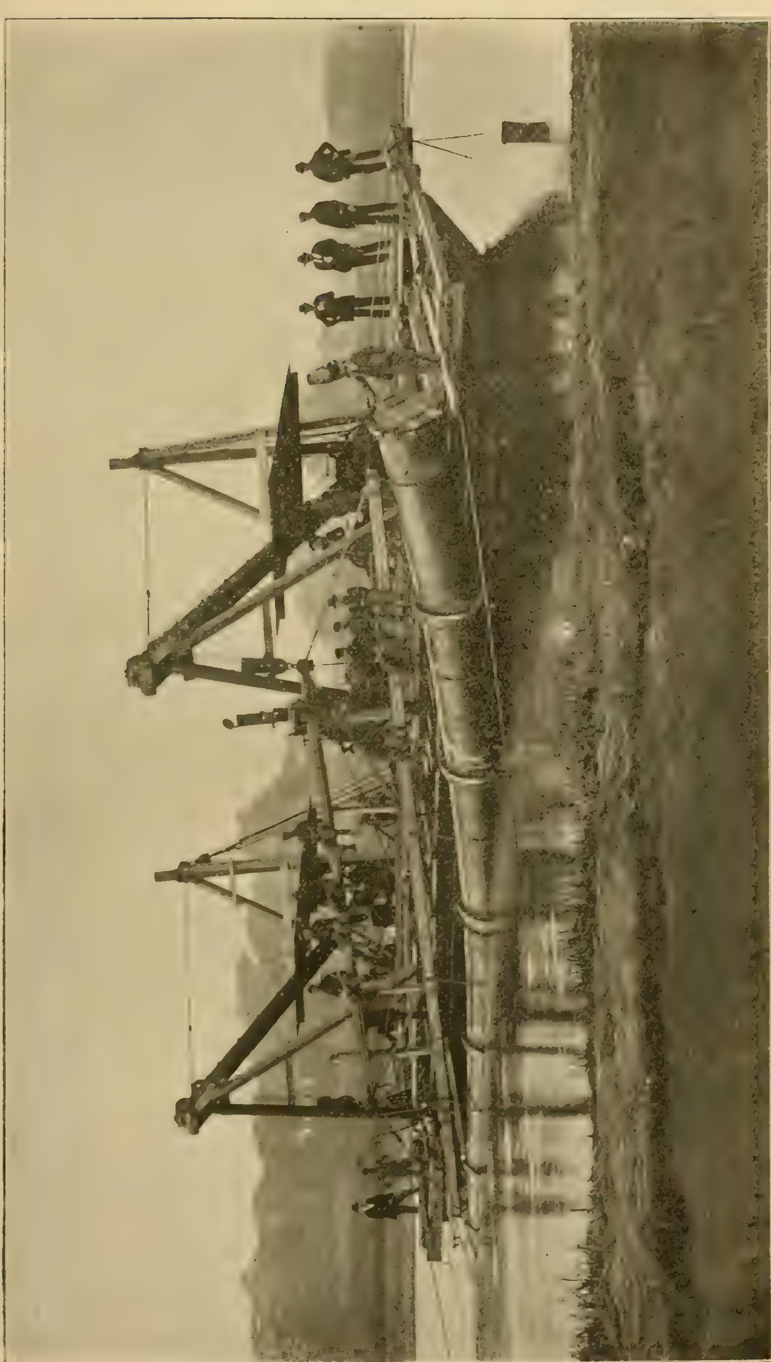


PLATE X. LAYING 36-IN. PIPE, CAMBRIDGE.

loading need never cause the pipe or tube to weigh more than a desired amount in water, thus making the work of hauling the pipe or tube across a simple matter. To diminish the amount of flexure of this pipe, it will be built on a vertical curve.

Once across, the 6-foot pipe is to be encased in concrete and this again loaded with rip-rap, upon which the interior bracing may be removed; the bracing to be made originally in form permitting of an examination or caulking of the pipe from the interior, while it is being hauled across.

So much being said, it follows that pipes or tubes of any diameter could thus be hauled across and underneath navigable waterways; and I have, in fact, proposed this method not only for the laying of sub-aqueous gas and water pipes and sewers, but also for the construction of sub-aqueous tunnels.

In the case of gas and water pipes and sewers, the method above described is by far the most economical, and produces, moreover, a tight and durable pipe, where flexible joints would give trouble from excessive leakage. The same advantage of reduced cost is true in most cases of sub-aqueous tunnels.

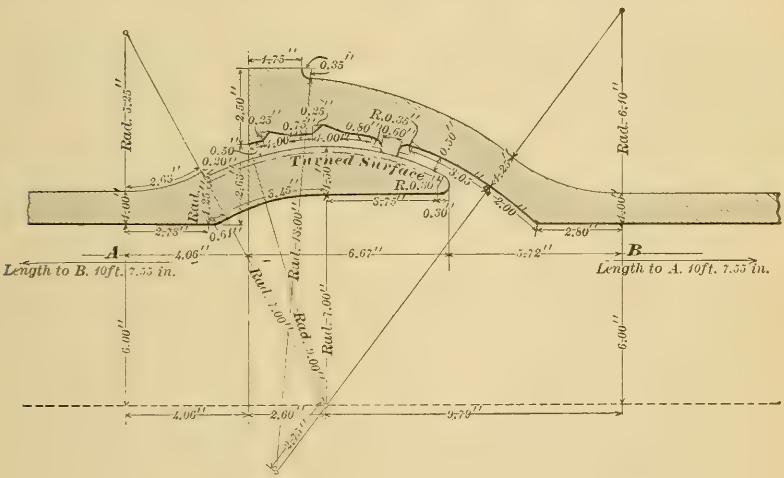
Mr. F. A. McInnes (by letter).—The methods recently employed by the Boston Water Department, under the direction of the City Engineer, in laying a 12-inch main under Shirley Gut, in Boston Harbor, differ from any described in the Saville papers, and, while extremely simple, may prove of some interest.

Shirley Gut is a short, narrow channel separating Deer Island from the mainland. At the point where the pipe crossing was made it is 350 and 150 feet wide, at high and at low water respectively, with 12 feet of water at low tide. At the same point, fifty years ago, it was 400 feet wide and 50 feet deep at low water.

A storm from almost any direction will often materially change its topography, while under the best conditions the sand and gravel, through which the channel flows, offer no inviting field for excavation, particularly as the current is extremely fast and the periods of slack water very short. These conditions demanded quick work, and made the possibility of failure unpleasantly prominent.

The pipe line was first put together on a cradle (on the Winthrop shore) extending back from high-water mark on a slightly rising grade. Under the cradle were 4-inch wooden rolls, resting on a platform. Each pipe was made fast to a 4-inch hawser, the latter being strained tightly as the "seizings" were made.. A trench, 5 feet deep, very wide on each shore and about 3 feet deep in midstream, was then dug across the channel. This part of the

work was done in four days by an ordinary dipper dredge, its success depending entirely upon good weather. The trench completed, it was necessary to finish the work with all possible speed. A $4\frac{1}{4}$-inch line, fastened to a "deadman" on the Deer Island shore, was carried across the Gut through a block on the 4-inch hawser at the end of the pipe; again across the Gut through a second block, and thence to a steam winch. At the first period of slack water, power was applied and the pipe moved readily, being kept on the platform by a number of men "cutting" the rolls as occasion demanded. As it entered the water, empty oil casks, which had previously been recoopered and fitted with fastenings, were tied to the pipe, the object being to reduce the weight a little more



SECTION OF 12-IN. FLEXIBLE PIPE.

Length over all, 12 ft. 6.67 in. Figured weight, 1815 lbs. Deflection, 1 in 4.5.

than one-half. It was absolutely necessary that the pipe should remain in the trench, at all points, out of the full force of the current. With a few slight interruptions, caused by its flexibility on the platform, the pipe moved steadily across the channel to a point about half way between high- and low-water mark. Here progress became so slow, and the strain on the ropes so great that it was deemed wise to "let well enough alone" and to lay the next two or three pipes at the succeeding low tide. At slack water the casks were cut away by a diver. After two or three small leaks near the shores were calked, the line was tested and found to be practically tight. The trench was then filled in. Under favorable conditions of small current and stable bottom, a short pipe line can be laid, very cheaply and safely, in the general manner described above.

The pipe used was one inch thick, weighing 1820 pounds per 12-foot length. It was of special design, very similar to one of the pipes described by Mr. Saville. The spigot is turned to a true spherical form, and a raised ring is also turned in the bell, to fit the curvature of the spigot. A stop prevents too much deflection in the joint. Two lead scores were used. This design, shown in detail in the accompanying figure, causes the lead to remain in the bell whatever position the pipes lay, a desirable point when joints must be calked under water.

EXTENSION OF THE GROUP THEORY OF ATOMS AND MOLECULES.

By Arthur A. Skeels, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, February 26, 1901.*]

The great importance of a clear understanding of the laws which govern the properties and phenomena of matter, both physical and chemical, is self-evident.

The great achievements of modern science are due to the fact that we understand nature and her laws better than did our fathers, and the still greater marvels to be accomplished in the future will be due to a still better insight into the natural laws which govern matter in its properties and transformations.

So vast is the importance of this knowledge that it is surely worth our while to consider *anything* which even *possibly* may give us a little more light upon the many difficult problems ahead.

The contents of this paper give a few of the results and conclusions of several years of study. The limits of the paper will naturally allow only a brief discussion of these conclusions, and,

Fig. 1

if some of the ideas advanced seem to be radically different from those commonly accepted, it must be remembered that, while a thing is not always advantageous because it is new, yet if we follow exactly in the footsteps of our predecessors we cannot hope to learn new truths.

Scientists in general believe matter to be composed of molecules, and the molecule to be made up of atoms. For example, a molecule of water is the smallest particle of water that can exist as water. The molecule of water is in turn taken as composed of two atoms of hydrogen and one atom of oxygen; but only recently has the possibility of the divisibility of the atom been seriously considered.

When light is refracted, as by passing through a prism, it is also dispersed; the waves of shorter length are separated from the longer ones, forming a spectrum. Different substances, in general, give out different kinds of light, and so form different spectra. The spectrum of hydrogen is approximately as Fig. 1.

*Manuscript received March 18, 1901.—Secretary, Ass'n of Eng. Socs.

The four lines show four different wave lengths of light, corresponding to 6562, 4861, 4340 and 4101 ten-millionths of a millimeter.

There may be other lines outside of the visible spectrum, not yet discovered, but at any rate the spectrum shows that hydrogen gives out light of at least four different wave lengths. If the vibrations of molecules produce this light, and if the molecules are exactly similar in all respects, how can they give four different wave lengths?

If the vibrations of atoms produce this light, how can the vibration of atoms, which are exactly alike in all respects, give four different wave lengths?

If the vibrations of both atoms and molecules produce the light, how can we account for more than two different wave lengths?

The spectrum of oxygen is approximately as Fig. 2.

That is, oxygen gives as many different wave lengths as there are lines in the spectrum. How can the vibrations of one kind of

Fig. 2

molecules or one kind of atoms produce so many different wave lengths?

It seems to me that the only logical conclusion is that the atom of oxygen is composed of as many parts as there are lines in the spectrum and that the vibrations of these parts cause the light. Also the different wave lengths show that these parts have different masses, or are acted upon by varying attractions while vibrating, or both.

The study of the spectra of all elements leads us to the same conclusions: that the atom is not the ultimate particle of matter; that the atom is composed of parts, and that the number of these parts may be determined, more or less accurately, by the number of different kinds of light emitted; that is, by the number of lines in the spectrum.

Upon this as a basis, aided by other important considerations which will appear as we proceed, we think we have good evidence to believe that in the same way that molecules are groups of parts called atoms, so are the atoms groups of smaller parts, which we may call sub-atoms. The sub-atoms are groups of still smaller parts, which we may call sub-subatoms; and by analogy these sub-subatoms are groups of even more minute parts, and so on until

a sub-atom is reached which is capable of no further division, and we have the ultimate atom.

We know that a few elements, by different groupings of the atoms and molecules, can form an almost innumerable number of compounds widely differing in properties. We go a step farther, and assume that all substances are made up by different groupings and compounded groupings of the ultimate atoms of one single absolute element.

The question now naturally arises, is this theory consistent with observed phenomena? Evidently the limits of this paper will not permit the discussion of all phenomena. We will consider some of the most characteristic.

We assume from the spectrum that the oxygen atom is composed of more than forty sub-atoms. The laws of gravitation alone will explain why these sub-atoms collect to form an approximately spherical group. The difference in wave length of light emitted by these sub-atoms is evidence that they differ from each other, and hence the atom cannot be homogeneous.

Fig. 3

Fig. 4

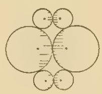


Fig. 5

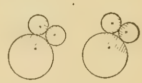


Fig. 6

While we would naturally expect that the heavier sub-atoms would collect at the center, we also would expect that, in the formation of the atom, centrifugal force, outside attraction or other causes might modify this.

The chemical behavior of oxygen seems to indicate that the atom has one side denser than the other, as shown by the shaded portion of Fig. 3. The center of mass, then, instead of being at the geometrical center of the atom, is displaced to within the shaded portion.

Two atoms of oxygen, placed as in Fig. 4, would have a much stronger attraction for each other than they could have for any other atom of oxygen, for no other can get its center of mass so near to be attracted. Hence ordinary free oxygen gas molecules are made up of pairs of atoms.

A very high temperature is necessary to separate these atoms, and a very low temperature is necessary in order that the twins shall have attraction enough to collect and form a liquid.

Similarly the chemical behavior of hydrogen indicates that its atoms also have a denser portion on one side, and that the free

gas molecules also exist in the form of twin atoms. We believe also, from the fewer lines in the spectrum, its smaller atomic weight, its greater diffusibility, etc., that hydrogen atoms are much smaller than those of oxygen.

If, at the ordinary temperature, oxygen and hydrogen gases are mixed, we may see by Fig. 5 that the centers of mass of the hydrogen molecules cannot get very close to the oxygen molecules; no particular attraction takes place, and hence no combination.

If, however, the temperature be raised to a point that breaks up the twins, the oxygen atoms are separated, the hydrogen twins can get nearer the centers of mass of the oxygen atoms, and a combination like Fig. 6 results, forming molecules of water. In changing from the grouping of Fig. 5 to that of Fig. 6 potential energy is changed to kinetic; that is, heat is given off.

Even at ordinary temperatures, the oxygen twin atoms, in collisions with other atoms, are continually subjected to strain, differing with the temperature, the atoms against which they impinge and the position of the atoms when struck; thus, at points below ignition, some of the twin atoms of oxygen will be broken up, leaving the single oxygen atoms ready to unite with the atoms against which they collide, and we say the substance is slowly oxidized.

The electric spark, in passing through oxygen, breaks up the twins, leaving separate oxygen atoms; but the passage of the spark is momentary, and the oxygen atoms, in rushing together again, in general, from ordinary twins, but some of them strike in such a way as to form triplets; that is, ozone. Fig. 7.

A comparatively slight disturbance dislodges one of the oxygen atoms, and the group of three becomes an ordinary pair and a single oxygen atom. The single dislodged atom, however, by reason of its dense part being exposed, is able to attract very strongly any other atom which may be near, hence the powerful oxidizing property of ozone.

An atom of oxygen may fasten to the side of a water molecule to form a molecule of hydrogen dioxide, Fig. 8; but this extra atom is easily dislodged, leaving a water molecule and a single oxygen atom; thus, like ozone, forming a powerful oxidizer.

In general any process which leaves single oxygen or hydrogen atoms leaves them in a position to unite powerfully with others; this is the so-called nascent state.

If we attempt to make any other compounds of hydrogen and oxygen, they must be made by putting the centers of mass of the added atoms so far away that the attraction is too weak to form a

stable group, hence the reason why the compounds of oxygen and hydrogen are so few in number.

We might assume the possibility of a molecule like Fig. 7, that is HO, but hydrogen atoms usually occur in pairs, and conditions which favor any combination would favor the combination of both atoms of the hydrogen pair. Even if molecules like Fig. 9 were formed, they would unite in pairs or twins and form H_2O_2, or hydrogen dioxide.

It has been found by experiment that at temperatures between 1146° and 2741° only one-half the usual amount of hydrogen will unite with oxygen. This seems to show that the dense part of the oxygen atom is not of uniform density, but rather as shown in Fig. 10. An atom of hydrogen, then, will be held more strongly at "a" than at "b." At temperatures between 1146° and 2471° the collisions are violent enough to dislodge the hydrogen atom clinging at "b," but not the one at "a," leaving the form of the molecule as HO.

The nitrogen spectrum consists of many fine lines, hence we conclude that the atom contains many sub-atoms. By the same

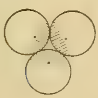


Fig. 7

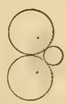


Fig. 8

Fig. 9

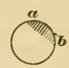


Fig. 10

course of reasoning already presented, we find the center of mass to be on one side of the atom and that the elementary molecule is a twin atom. The so-called inertness of nitrogen, that is, the difficulty found in getting free nitrogen to unite with other elements, gives us reason to believe that the attraction between the atoms in the elementary molecule is stronger than in oxygen. It is more difficult to separate the atoms of nitrogen to get them in a position to unite with other atoms. The fact that a single atom of nitrogen unites with three atoms of hydrogen to form ammonia suggests also this stronger attraction, or at least that the dense portion of the nitrogen atom occupies a larger portion of the side than in the case of oxygen.

It will also be noticed that it requires a much lower temperature to liquefy NH_3 than H_2O. This shows that the attraction between molecules of H_2O is stronger than between molecules of NH_3, that at a given temperature the molecular velocity of H_2O is less, or that it depends upon both taken together.

A study of the boiling points, freezing points, relative chemical attractions and atomic weights, together with the forms of crystal-

lization, hardness, ductility, etc., will give data from which to determine, approximately, at least, the positions of the centers of mass of the different molecules and atoms.

In the case of nitrous oxide, Fig. 11, we have a group of three atoms. When the temperature reaches a certain point the group is broken up, the two nitrogen atoms unite to form a pair, leaving the oxygen atom in the single form ready to unite with other atoms; that is, nitrous oxide acts as a powerful oxidizer after the temperature has reached a certain point.

Fig. 12 shows a molecule of nitric oxide. The molecule of N_2O is more easily decomposed than NO, because the two atoms of nitrogen in N_2O tend to form a twin atom or elementary molecule. This aid to an outside force is not present in the molecule of NO. However, at a very high temperature the NO is decomposed, leaving the oxygen free, and it is then a supporter of combustion.

Let us now pass to chlorine. When a free gas, this also exists as twin atoms, showing the center of mass of the atom to be nearer one side.

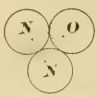


Fig. 11

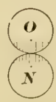


Fig. 12

It would seem that the dense portion of the atom is in a comparatively small spot, since but one atom of hydrogen is held, as in hydrochloric acid. The small attraction of the chlorine atoms for each other is shown by the comparative ease by which the elementary molecules are broken up, leaving the chlorine atoms in a position to be very active in combining with other atoms.

Activity in combination, however, is not necessarily the same as power of combination. Two atoms may readily unite, and yet not powerfully unite.

Since light is produced by the vibration of the sub-atoms, conversely, light will cause the sub-atoms to vibrate, the atoms will expand, the centers of mass of the atoms will move farther apart, the attraction between them will become less and the elementary molecules may be more easily broken up. Hence, light facilitates combination of chlorine with other atoms. In a similar way light, by expansion of the atoms, changes the equilibrium and combinations in photographic processes.

Of course light would tend to produce the same effect in a great many substances, but the laws of sympathetic action, together

with other forces, would, in general, cause this effect to be unnoticeable.

Bromine, iodine and fluorine resemble chlorine, so we need not stop with them here except, perhaps, to consider the remarkable fact that fluorine will not, as far as known, combine with oxygen. If it is impossible to form compounds of oxygen and fluorine, it may mean nothing more than that the oxygen atoms have a stronger attraction for each other than they do for the fluorine. That is, if such a combination were conceived, it would be broken up by the oxygen atoms uniting to form twins or free oxygen molecules.

Carbon seems to have four dense parts in its atom. If we imagine surfaces "ab" and "cd" passed through the atom, we may consider each of the four portions to have a center of mass of its own. Four hydrogen atoms then would naturally cling, as shown by Fig. 13, representing CH_4.

Some other representative compounds are as shown below:

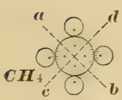


Fig. 13

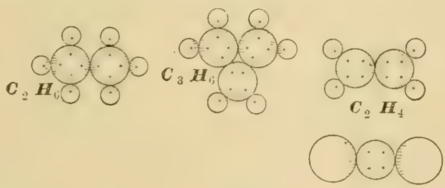


Fig. 14 *CO2*

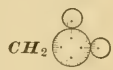


Fig. 15

It would seem reasonable to suppose that the four dense portions of the carbon atom would not be exactly the same; that is, their attractive powers would be different. The compound CH_2 would tend to show that the attraction is stronger upon two sides, forming the group of Fig. 15. The compound CO tends to show the same thing. One oxygen atom taking the place of the two hydrogen atoms of CH_2.

The compounds CH_2 and CO would naturally be formed when there was a scarcity of hydrogen or oxygen, the stronger sides of the carbon taking up all of the atoms of hydrogen or oxygen.

Instead of forming twin atoms, as do oxygen, hydrogen, etc., free carbon tends to collect indefinitely, since there is a strong attraction on four sides. It therefore tends to form a solid which requires an extreme high temperature to vaporize. The two forms of crystals show two different arrangements of the atoms, the octahedral or diamond, shown in section by Fig. 16, and the hexagonal or graphite, as shown in section by Fig. 17. The diamond having the dense portions in closer proximity to each other tends to give a stronger attraction, hence the greater hardness.

Amorphous carbon is quite possibly a mass of extremely small crystals of graphite.

The ability to attract in four directions makes carbon a powerful link in binding together other atoms. It connects the atoms of soft iron to make hard steel, while most of the molecules in the organic world would fall to pieces were it not for the powerful cementing influence of the inclosed carbon.

The spectrum of sulphur leads to the conclusion that its atom has a great many sub-atoms, and a study of its properties leads us to believe that the atom has two dense parts or centers of attraction at about 90° from each other. The sulphur naturally existing in clusters of six atoms, as would be represented by Fig. 18, if we conceive an atom in the center front and another in the center back. Collections of these clusters would make octahedra, the natural form of sulphur crystals. When the sulphur is heated the clusters of six move more freely amongst each other; the sulphur melts.

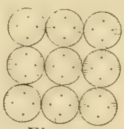


Fig. 16

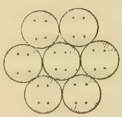


Fig. 17

At a higher temperature two of the atoms of the cluster of six are dislodged, leaving the cluster of four as shown by Fig. 18. The atoms disengaged uniting to form other clusters of four. The cluster of four, however, still retains considerable attraction in two directions, those from which the two atoms were dislodged, and by continually clinging to its neighbors (though but weakly) is retarded in its motions; the liquid sulphur becomes viscous. At a higher temperature, however, this tendency is overcome and it becomes liquid again.

Suddenly cooling the viscous sulphur will increase the side attraction, without giving time to arrange in crystals, by bringing the clusters nearer together, hence the rubber-like mass.

Clusters of four will evidently form different crystals than clusters of six; they form rhombic or monoclinic crystals, which, however, gradually revert to the natural or cluster of six form. This change, as we might expect, is facilitated by heat or vibration.

In general, the crystal forms will aid us greatly in locating the relative positions of the dense portions of the atoms. The cleavage and fracture will also be important helps.

If it is true that the atoms are made up of sub-atoms, it seems

quite within the limits of possibility to find some way to break them up and make new elements of the fragments. We may even advance to the point where we can make a given element out of other elements as we now make a given compound out of other compounds. When this day arrives the old dream of the alchemists may find its realization; we may be able to make gold.

It has been found that the spectrum of sulphur, as well as many other elements, differs at different temperatures.

Light is caused by the vibrations of the sub-atoms and possibly some of the smaller groups of sub-atoms. As the mechanical collisions set the molecules of a body vibrating, so will the collisions of the molecules set the atoms vibrating, and, in the same way, the collisions of the atoms will set the sub-atoms vibrating and produce light.

In the same way that the vibration of the molecules expands a body, so will the vibrations of the atoms expand the molecule, and the vibrations of the sub-atoms expand the atom. But this disturbance among the sub-atoms very likely would modify the group-

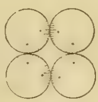


Fig. 18

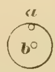


Fig. 19

ing and certainly modify the attractive force among the sub-atoms, and change the frequency of the vibrations, which would mean a change in the spectrum.

Suppose "a" and "b," Fig. 19, be two sub-atoms of exactly the same mass, but "a" is at surface of atom and "b" in the interior. "a" and "b" would have different vibration frequency, because they are acted on by different attraction, analogous to pendulums on and below surface of the earth.

If the light waves caused by the vibrations of the internal sub-atoms can get out of the atom, we would have all wave lengths corresponding to these different attractions from circumference to center; and, if the sub-atoms were numerous, a band spectrum, even though the sub-atoms were all of the same size. With sub-atoms of different mass, the band spectrum would vary in density.

On the other hand, if the atom be opaque, only the surface sub-atoms can send out light and we have a different wave length for each different kind of sub-atom; that is, we have a line spectrum.

Evidently, an atom partially opaque would have a combination of line and band spectrum.

That some lines are brighter than others may be explained by saying there are more sub-atoms of that particular kind than others, and hence give more light; or that some sub-atoms are near the surface of the atom, and hence give more light than those partly covered up.

Even the surface sub-atoms of the atoms would be affected by the proximity of other atoms; and a change in the temperature, bringing about a change in the position of the atoms, would affect the vibration number of the sub-atoms, and hence a change in the spectrum.

An element in the gaseous form giving a line spectrum, because the vibrations of the sub-atoms are nearly unaffected by the proximity of other atoms, will give a continuous spectrum in the liquid or solid form, because, as we go from the surface of the liquid or solid downward, the sub-atoms are gradually more and more affected, and have their wave lengths gradually changed, hence producing all the wave lengths between certain limits.

In vibrating, a body sets up sound waves in the air, a substance whose molecules are of similar magnitude to the molecules of the vibrating body. Analogously, the sub-atoms, in vibrating, set up light waves in the ether, a substance whose particles are of the same or similar magnitude as the particles of the vibrating sub-atom; that is, the ether is a gas-like substance whose particles are sub-subatoms.

Furthermore, analogy and a study of phenomena lead us to believe that there is another gas-like substance, occupying a position between the ordinary gases and the ether, a gas-like substance whose particles are sub-atoms. We may call this a sub-gas.

In general, then, the smallest particles of ordinary gases are composed of pairs or groups of atoms. The smallest particles of a sub-gas are pairs or groups of sub-atoms, and the smallest particles of the ether are pairs or groups of sub-subatoms.

Furthermore, since we have a variety of different gases, so we may have a variety of different sub-gases, a variety of different ethers, and even a variety of different sub-ethers, etc.

Here are substances fine and delicate enough for the enthusiast to build up the principle of life existing in germs, to fashion the intellect, memory, yes, even to construct the human soul.

Bodies vibrating in ordinary gases produce sound waves, sub-atoms vibrating in the ether produce light waves. Analogously we might expect that atoms or clusters of atoms vibrating in the sub-gas would produce a set of waves which can not be classed among sound or light waves.

When a body is heated, its molecules are caused to vibrate, and at the same time it gives off what is termed radiant heat. Is it possible that this radiant heat consists of waves in the sub-gas instead of (what is generally assumed) in the ether? We have thus far failed to recognize a single fact which would show that radiant heat could not be a wave motion in a sub-gas as well as in the ether. It would seem that, if the velocity of radiant heat, or even perhaps the wave length, could be determined independently of any connection with light, this doubt could be cleared up. If radiant heat were a wave motion in a sub-gas, its wave length would be much greater and its velocity much less than those of light.

Phenomena seem to show that electricity is a motion in the sub-gas, while magnetism is a motion in the ether. A discussion of this, however, does not properly belong to this paper, which discusses the constitution and properties of matter, rather than the motions of matter. The motions of matter are, however, so intimately connected with the properties and constitution, that it is impossible to separate them entirely.

Mechanical collisions form molecular vibrations or heat; molecular collisions, or heat, produce vibrations of the sub-atoms, or light. Mechanical energy can be changed to heat and vice versa. Molecular energy, heat, can be changed to light and vice versa.

Some substances require less mechanical energy than others to raise the molecular vibration sufficiently to send out radiant heat. Similarly some substances require less molecular energy, heat, to raise the vibration of the sub-atoms sufficiently to send out light. As substances have different "specific heats," so do they have different "specific lights." Phosphorus is a substance of low "specific light;" a comparatively low temperature or slight collision of the molecules causes the sub-atoms to vibrate enough to send out light.

When light rays fall upon a substance the light vibrations set the sub-atoms vibrating, especially if the sub-atoms naturally send out that same kind of light. By reason of inertia, these sub-atoms continue to vibrate for a short time, even after the exciting rays are cut off, and thus give out or glow, as shown in the phenomena of phosphorescence.

Calorescence, the changing of heat rays to light rays, would be a change of energy form, analogous to change of sound to heat, when sound waves are absorbed by a body. The converse, the change of light to heat, would be analogous to the change of heat to sound, as is illustrated by numerous examples.

Whether there are any motions in the sub-ether which man is able to detect is a question. Possibly, however, if we can accept as a fact what thousands have asserted, and what thousands and millions believe, that there is a mysterious connection between mind and mind, this connection may be through the sub-ether.

If the molecules of a substance have the centers of mass close together, as in Fig. 20, they attract each other strongly, the substance is hard; but if a force sufficiently strong acts, a small actual motion in almost any direction becomes a large relative motion, the molecules are permanently torn apart, there is no appreciable "give" to the substance, we say it is brittle. Carbon affords a good example of this. If, on the other hand, the center of mass is at or near the geometrical center, Fig. 21, a much smaller force will cause a much larger actual motion without affecting the relative distance so much and without affecting the actual attraction very much. The body is not ruptured. The less force shows the body to be soft. The molecules will roll around each other, there being about as much attraction in one position as in another; the substance is ductile or malleable.

Fig. 20

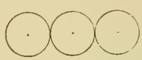


Fig. 21

One body may be harder than another, showing a greater attraction between the molecules, and still be found by experiment to be less tenacious than a softer body which has less molecular attraction.

This is due simply to the fact that the molecules of the harder body have but little "give" to them. A stress in any direction will cause a great strain on some molecules and none on others; these molecules pull apart, throwing the stress upon others; these give way, then others, and so on until the rupture is complete. It is like breaking a great cable one strand at a time. In the softer body, however, the molecules "give," so before any rupture takes place the whole cross-section of the body is resisting the stress. It is practically stronger than the first body, notwithstanding that its molecular attraction is less.

It would seem that the rigidity of solids furnishes almost positive proof that their molecules are not only actually, but relatively close together, that at absolute zero the molecules and atoms are as much in contact as are the stones in a stone pile. At any other temperature the relative distance apart is but small, and can be cal-

culated from the amount of expansion from the absolute zero to the given temperature. For example, if a solid increases its length 0.25 per cent. when heated from absolute zero to any given temperature, the distance between the centers of the molecules will also increase 0.25 per cent. Also since the change from a solid to a liquid is usually accompanied by but a slight change in volume, the liquid molecules and atoms are also very nearly in contact. Hence the relative densities of the molecules and atoms of liquids and solids are approximately the same as the relative densities of the liquids and solids themselves.

We may use this principle to determine the approximate sizes of different molecules. For example, the molecular weight of sulphuric acid is about 98, about 5½ times that of water. That is, a molecule of sulphuric acid has about 5½ times the mass of a molecule of water. If the molecules of sulphuric acid were of the same size as those of water, the density would be about 5½; but being only 1.8 about, or about 1-3 as much, it means that a molecule of sulphuric acid has about three times the volume of a molecule of water.

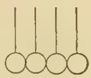


Fig. 22

If a series of pendulums, as shown in Fig. 22, were made of ivory or glass balls, they could be made to vibrate at a certain amplitude amongst each other with much less expenditure of energy than if the balls were made of lead; the leaden balls would absorb much more energy in themselves. Different substances are made up of different atoms and molecules. Naturally some of the atoms and molecules are more elastic than others and require less energy to raise their temperature; they are said to have a low specific heat.

We find the specific heat of hydrogen to be 3.409, and that of oxygen 0.2175. Approximately (1), Sp. Ht. of O $\times$ Mol. Wt. $=$ Sp. Ht. of H $\times$ Mol. Wt.

One gram of H requires about 16 times as much energy to raise it one degree as one gram of O. Therefore one volume of H requires about the same energy to raise it one degree as one volume of O. This means that it requires about the same energy to raise one molecule of H one degree as one molecule of O.

But equation (1), given above, is only approximately correct. If the specific heat of O were 0.2129, instead of 0.2175, the equation would be exactly correct; that is, the actual specific heat of O

is a little greater than the theory of equation (1); that is, the molecule of O requires a little more energy to raise it one degree than the molecule of H. This extra energy required is due to the energy absorbed by the internal parts of the O molecules. Collisions of the molecules set the atoms and sub-atoms vibrating, thus taking up some of the energy; but the O molecule, being more complex than the H molecule, absorbs more energy.

Take a molecule of steam, instead of oxygen, in equation (1). If the specific heat of steam were 0.378 instead of 0.48, equation (1) would be true; that is, more heat energy is required to raise one molecule of steam one degree than a molecule of hydrogen, and not only more, but relatively more than to raise a molecule of oxygen one degree. Much more energy is absorbed by the internal parts of the steam molecule than by the H or O. It is more complex.

Water has about twice the specific heat of steam. The molecules are closer together, the collisions are more frequent, the internal disturbance is greater, and hence the greater amount of energy absorbed by the atoms and sub-atoms.

If we use equation (1) to compare water with common salt, the calculated specific heat of the NaCl is 0.307, but the real Sp. Ht. is 0.219, hence the amount of energy to raise one molecule of NaCl one degree is less than that of water. The NaCl is less complex. If we compare water with potassium sulphate, the calculated specific heat of the K_2SO_4 is 0.103, while the real Sp. Ht. is 0.196; that is, the molecule is so complex that it requires more energy to raise one molecule of K_2SO_4 one degree than one molecule of H_2O. More energy is absorbed in the internal groups.

If we compare lead and tin, the calculated Sp. Ht. is 0.0552, the real Sp. Ht. 0.0548; that is, each molecule requires about the same energy to raise it one degree, about the same amount of energy is absorbed by the internal parts of each molecule. This same agreement holds for all the metals as well as chlorine, bromine, iodine, selenium, tellurium and arsenic. If we compare hydrogen and lead, using a molecule of H and an atom of Pb the calculated Sp. Ht. of the Pb is 0.0330, the real Sp. Ht. is 0.0315, showing that the energy required to raise a molecule of H and an atom of Pb is about the same.

We interpret this to mean, in general, that all kinds of molecule require the same energy to raise them one degree (remembering that a molecule is sometimes composed of but one atom), except for the part of the energy which is absorbed by the internal groups of the molecule.

But when molecules are raised one degree it means that they are capable of imparting a certain additional energy to a thermometer; so when we say that all molecules, except as above mentioned, require the same energy to raise them one degree, we are simply saying that the same energy given to all kinds of molecules will enable them to give the same additional amount to a thermometer; that is, in other words, that the same energy given to all kinds of molecules will increase their energy the same amount. This is, of course, self-evident, and the whole investigation shows that part of the heat energy is absorbed in the internal groups of the molecule, and that atomic heat is no special property, but a natural consequence following the different molecular weights.

There seems to be little doubt that a body is raised in temperature when the kinetic energy of its molecules is increased. Potential energy has nothing to do with temperature. When water is turned to steam the molecules move farther apart, the potential energy is increased at the expense of the kinetic energy, and is apparently losing heat; this, together with the energy taken up in the interior groups of the molecules themselves, accounts for the latent heat of steam.

In the same way that vibratory motion can be transmitted through a row of elastic balls more easily than through inelastic ones; so can heat be conducted through a substance composed of elastic molecules and atoms more easily than through inelastic ones. This would tend to show that bodies with low specific heat would be good conductors; but this conductivity is modified by the attractive forces which may prevent the molecules from readily moving to communicate the heat motion to its neighbors.

We know that light passes through certain bodies which we call transparent. Either the light passes as ether waves between the atoms like water waves between rushes or else the vibrations pass through the substance itself like sound passes through a wall. A thin layer of ordinary carbon is perfectly opaque, while a thick and much denser layer of diamond is transparent. Facts like this seem to point to the latter explanation. The transparency of a body, then, will depend upon the elasticity, continuity and freedom of motion of the sub-atoms.

In the same way that mechanical vibration will be absorbed by a non-continuous mass, like sand, or inelastic matter, like lead, so will light vibrations be absorbed by inelastic and non-continuous sub-atoms.

The irregular expansion of water may be explained as follows:

When heated from the ordinary temperature, water gradually expands, but the rate of expansion gradually increases as the tem-

perature rises. The high specific heat of water shows that the molecules are inelastic. A great deal of energy is absorbed by the molecules themselves, but this absorption of energy causes a vibration of the parts within the molecule, and the molecule itself expands. This gradual increase in the size of the molecules, added to the regular expansion, causes the increase in the rate of real expansion. When water cools, it contracts to 4° C., then expands slightly, then greatly as it freezes. Water crystallizes in hexagonal plate-like forms; that is, when the vibration of the water molecules becomes slow enough, gravitation draws them together, forming hexagonal clusters of six, Fig. 23. In this form the centers of mass are as near as possible. This forms the elementary crystal, and, by collections of these, all the varied forms shown by snowflakes are built up.

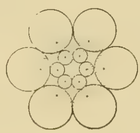


Fig. 23

A few of these clusters begin to form at 4°, and this arrangement take up more room. The water expands. When all form hexagonal clusters, the water becomes ice and the expansion is considerable.

The six water molecules in the cluster are held together as in a vise. The relative vibration is largely stopped, and this kinetic energy is given to outside bodies. The cluster of six then acts as a molecule. When ice again melts, it naturally requires considerable energy to again break up these clusters, hence the apparent disappearance of heat. This hexagonal molecule of water plays an important part in the formation of many crystals, as water of crystallization. The occurrence of $6H_2O$, $12H_2O$ $24H_2O$, etc., suggests this. Other groups seem to be formed by replacing one or more of the water molecules in the hexagonal molecule by another atom or molecule; for example, the compound, $Cl + 5H_2O$.

ENGINEERING EXPLORATIONS IN MONTANA AND ELSEWHERE IN THE ROCKY MOUNTAINS.

Annual Address of Francis W. Blackford, Retiring President Montana Society of Engineers.

[Read before the Society, January 12, 1901.*]

I had read with interest the journals of most of the expeditions mentioned in this paper before I had ever set foot west of the Mississippi River or thought of making my home in Montana, but later professional work took me over a large extent of the country traversed by them, and I again read the journals with increased interest, and from my acquaintance with the country was enabled to locate the various routes of travel in accordance with present geographical terms. Others might have the same interest in such things, but not the time or opportunity to gratify it. I therefore selected this as my subject.

These explorers pointed out the way and stimulated immigration and permanent settlement, which made possible the construction of the Union and Northern Pacific Railways, great undertakings and great engineering work in any age. The period of exploration covered pretty well the first three-quarters of the century and I deem it not improper to review them now at its close.

Such a review would logically begin with the expedition of Lewis and Clarke, which started from a point on the Missouri River, near the present site of Kansas City, in the spring of 1804.

Lewis and Clarke were both captains in the United States Army, and the expedition was organized and equipped by the authority of the Government to explore a part of the then recent Louisiana purchase. The instructions of the commanders were, briefly, to follow the Missouri River to its head, thence cross to the head waters of the Columbia and follow it to its mouth, and come back overland if practicable. In pursuance of these instructions this expedition traveled by a keel-boat and canoes to a point near the present site of Bismarck and went into winter quarters, where they spent the winter of 1804 and 1805. As soon as the river was free from ice in the spring they resumed their journey and reached the Great Falls of the Missouri, the first interruption to traffic, in the month of June, 1805. After a laborious portage of their goods, they again embarked in canoes made above the falls and continued up the Missouri to the Three Forks thereof, thence by the Jefferson to the confluence of the Big Hole and Beaverhead, thence by the

*Manuscript received March 8, 1901.—Secretary, Ass'n of Eng. Socs.

Beaverhead to the Horse Prairie, thence by said creek until it became too shallow for their boat. Here they made a cache and proceeded by pack train, composed of horses purchased from the Indians, and under the direction of Indian guides, over Horse Prairie and across the main range of the Rocky Mountains to a tributary of the Salmon, thence down said stream to a point near the present site of Gibbonsville, thence almost due north across a high spur of the main range to Ross Hole, in the Bitter Root Valley, thence down the Bitter Root Valley to a point some six miles south of the present site of Missoula, thence westward by what was known as the North Nez Perce Trail, up the Lolo to the summit of the Bitter Root Mountains, down on to the waters of the Clear Water, and up again to the higher ground lying between the Clear Water and Clark's Fork of the Columbia, upon which ridge and its spur the trail lay for many miles, finally taking them to the Clear Water near its confluence with the Snake, at which point they made boats and reached the mouth of the Columbia in December of 1805.

Returning, the expedition traveled by the same route as far as the mouth of the Lolo, near Missoula, where a separation took place. Captain Clarke and part of the party went up the Bitter Root Valley to Ross Hole, thence across what is now known as Gibbons Pass to the Big Hole Basin, thence south to Horse Prairie and the cache made the year previous. They then proceeded down the valley of the Beaver Head and the Jefferson to the Three Forks of the Missouri, where the party again divided, a part joining Captain Lewis with the boats at the Great Falls of the Missouri, while Captain Clarke proceeded up the Gallatin and its tributaries, passing near the present site of Bozeman to Bozeman Pass of the Belt Mountains, and to the Yellowstone River near to where Livingstone now stands. There they made boats and proceeded down the Yellowstone to its mouth, near which, in August, 1806, they met Captain Lewis, who had left the mouth of Lolo at the same time and traveled as follows: Down the Bitter Root to the Hell Gate, up that stream to the mouth of the Big Blackfoot, thence up the Big Blackfoot to its head, crossing the main range of the Rocky Mountains at what is now known as Lewis and Clarke Pass, thence to the Great Falls of the Missouri, where they embarked and proceeded down the Missouri to the mouth of the Yellowstone, near which they met Captain Clarke.

In the year 1806 Lieutenant Pike, of the United States Army, ascended the Arkansaw River to a point near its source and returned via the South Platte, discovering, upon his way, the peak

which now bears his name and which has always been a prominent landmark for a large section of the State of Colorado. The honor of first ascending this peak, however, belongs to Dr. James, of Major Long's expedition. This expedition approached the mountain via the South Branch of the Platte in the year 1820. The high peak lying some sixty miles northwest of Denver gave this expedition the first glimpse of the Rocky Mountains, and has since been known as Long's Peak. Major Long gave the name of James Peak to the mountain first seen by Lieutenant Pike. Notwithstanding this, the name of Pike has stuck to the peak first seen and reported by him, and the name of James has been given to the peak lying immediately south and about ten miles distant from Long's Peak. I have stood upon the summit of the last-named peak, which is somewhat lower than either Pike's or Long's Peak, both of which are visible from its summit.

The view from this point is very impressive, and, in addition to its grandeur, gives one an excellent knowledge of the geography of the surrounding region.

Major Long's party did not penetrate the mountains very far, but confined their explorations to the district lying east thereof. The next expedition of importance was that of Captain Bonneville. This was semi-official in its character, and more a fur-trading than an exploring expedition. Captain Bonneville was an officer in the United States Army and had served on the frontier; being desirous of extending his knowledge of the country lying to the westward, he obtained from the Secretary of War a leave of absence with the understanding that upon his return to the army he was to report the result of his travels and explorations to the War Department. He then associated himself with some capitalists who furnished the means to outfit a trading and trapping expedition. The outfit consisted of about one hundred men with wagons and pack animals. It started from the frontier in the spring of 1832 and traveled westerly to the North Platte, thence by the North Platte to the Sweetwater, thence by the Sweetwater to South Pass, thence to Green River, where a cache was made, which remained the headquarters of the expedition for the next three years. Captain Bonneville was the first to cross the Rocky Mountains with wagons.

He then went up Green River and on to the Snake River at what was then known as Pierre's Hole, a valley lying immediately west of the Three Tetons, this was a general rendezvous for the trappers of the American and Rocky Mountain Fur Company. The country, even at that early period, was full of trappers, who

went in every direction from this point in search of fruitful fields for their occupation.

Captain Bonneville's expedition did not prove a financial success, but, during his three years' sojourn in the mountains, he traveled extensively and increased the knowledge of the geography of this section of the country, which was then very meager. He made two trips from the Green River around the eastern slope of the Wind River Mountain to the Yellowstone; spent one winter upon the head waters of the Salmon, immediately west of Horse Prairie; traveled upon the Beaver Head and its tributaries, and spent a part of one winter near Fort Hall, a trading post situated on the Snake River, near the mouth of the Portneuf.

In the year 1834 he made two trips down the valley of the Snake River, up the Malheur via Grand Rond Valley, across the Blue Mountains and down the John Day River to Walla Walla, returning by practically the same route. In traveling from Fort Hall to Green River he sometimes went by the way of Pierre's and Jackson's Hole, and sometimes by the Portneuf or Blackfoot and Bear River to Sublett's Pass and Ham's Fork, following very nearly the route afterward taken by the Oregon Short Line Railway.

Finding a herd of buffalo imprisoned by the snow in the valley of Bear River in the winter of 1834 and 1835, the expedition, or what was then left of it, camped with the buffalo until spring, it is needless to say to the discomfiture of the latter. They then proceeded eastward via the South Pass and Platte River, reaching the settlements in August, 1835.

In July, 1833, a detachment from this expedition traveled down Bear River to the Great Salt Lake and made an exploration partly around its southern end. They then struck across the desert lying to the westward, and after various adventures and extreme hardships crossed the Sierra Nevada Mountains to the valleys of California.

Returning, they crossed the mountains further south, probably by the Tehachapi Pass, thence to the southern end of Salt Lake and via the Bear River to the rendezvous on Green River.

It was the intention of Captain Bonneville to have this party thoroughly explore the Great Salt Lake, of which little was then known. The leader and his men proved unreliable, however, and wasted their stores and means in the trip to California, and added but little to the knowledge either of the extent of the lake or of the country thereabout.

This lake was called Lake Bonneville by Washington Irving in his "Astoria," but it was well known before Captain Bonne-

ville visited the country, having been seen and reported by James Bridger, a trapper, in 1825. It may have been discovered by the Spaniards at an earlier period, but their information concerning it was very vague and uncertain.

The next exploration, in the order of occurrence, was that of Lieutenant John C. Fremont, who made three expeditions to and beyond the Rocky Mountains, beginning in 1842 and ending in 1846.

Fremont was eminently fitted for such work, having had several years' practical experience as a civil engineer engaged in railroad surveying and kindred work, notably a reconnaissance for a railway from Charleston, S. C., to Cincinnati, over a very broken and mountainous country. He was also an accomplished mathematician, having been instructor in the United States Navy. At the time of his appointment as chief of this exploring party, he was an assistant engineer in the engineering department of the army.

During all of his expeditions he was supplied with instruments for obtaining temperature, latitude, longitude and altitude, and such determinations were frequently made, except at rare intervals when his instruments were broken or out of repair.

His descriptions of the country traversed are so full and plain that his route can be easily followed, by means of these alone, by any one who is at all familiar with the topography of the country. I have surveyed railway lines over more than a thousand miles of his trail, and have traveled by wagon and in other ways over other parts of it, and can, therefore, speak from personal observation.

The object of these expeditions was mainly to increase the geographical knowledge of the country for the aid and encouragement of immigration to Oregon and the Northwest.

The first expedition left the Missouri River, near the mouth of the Kansas, in June, 1842, traveled northwesterly, thence via the Main Platte and its South Fork, reaching the base of the mountains just east of Long's Peak, near St. Vrain's Fort. Thence the route lay along the eastern base of the mountains to the North Platte River, thence via the Platte and Sweetwater to South Pass. The latter he described as being so extremely easy of access that it was only by the most careful observation that the highest point could be discerned.

From South Pass the party traveled toward the Wind River Mountains, and, after a number of days of arduous labor, Lieutenant Fremont and several of the party succeeded, on the 25th of August, in reaching the summit of the highest peak of the range,

and planted thereon the American flag. This peak has since born his name, and it was thought then to be the highest peak in the Rocky Mountains.

The party then retraced their steps as far as Fort Laramie, and from there followed down the Platte to its mouth. Then, by boats built for the purpose, they descended the river to St. Louis, where they arrived on the 17th day of October, 1842.

Fremont's second expedition was much more extensive than the first, and the results were of greater geographic value. His instructions were to connect his reconnaissance of 1842 with the surveys of Captain Wilkes, of the United States Navy, on the coast of the Pacific Ocean, near the mouth of the Columbia River.

This expedition left the mouth of the Kansas on the last of May, 1843, traveled nearly westward to St. Vrain's Fort, at the base of the mountain, thence southward to Pueblo, up the Arkansaw about seventy-five miles, across to the South Platte in South Park, thence to St. Vrain's Fort, making a reconnaissance completely around Pike's Peak, and including much of the head waters of the Arkansaw and the South Platte.

Leaving St. Vrain's Fort on July 26, they passed up the Cache La Poudre to the tributaries of the Laramie River, thence along the eastern slope of the Medicine Bow Mountains, over the Laramie Plains, striking the Sweetwater a short distance east of South Pass, thence by the Emigrant Road to Green River, at a point about twenty miles north of the present crossing of the Union Pacific Railway.

From here they traveled westward to Ham's Fork, up that stream to the dividing ridge between the waters of the Colorado and those of the Great Basin, crossing the same very near, if not at, Sublett's Pass, now occupied by the Oregon Short Line Railway, thence down a tributary to Bear River, which stream they followed to Soda Springs, thence by the Portneuf to Fort Hall in the Snake River Valley. From near Green River to Fort Hall the route followed very closely that taken forty years later by the Oregon Short Line.

While the main party was journeying down the Portneuf, Lieutenant Fremont and a few men traveled from Soda Springs down the Bear River to the Great Salt Lake, and explored its eastern shores as far as the mouth of Weber River. He visited one of the islands, from which he obtained a good idea of the extent of the lake.

He then traveled northward to Fort Hall, following up the Malad and down Bannock Creek instead of the route afterward

followed by the Utah and Northern Railway, which lies a little to the eastward.

His route then lay down the valley of Snake River to Burnt Fork, thence up that stream and on to the Powder River, passing near the site of Baker City, thence via the Grand Rond Valley, across the Blue Mountains to the Columbia River, near Fort Walla Walla.

There were a few white inhabitants engaged in the fur trade along the route of travel from Fort Hall to this point, notably at the mouth of the Boise and in the Grand Rond Valley. There were also emigrants along the way bound for the valley of the Willamette.

Leaving the main party at the Dalles of the Columbia, Lieutenant Fremont proceeded to Fort Van Couver, near the mouth of the Willamette, where he laid in a supply of provisions for his contemplated explorations southward from the Dalles. He had thus fulfilled his mission and connected his survey with that of Captain Wilkes.

Lieutenant Fremont reports that Mount Rainier and Mount St. Helen were then in action, the latter having scattered ashes over a large extent of country the year previous.

The extent of the Great Basin lying between the Wasatch and Sierra Nevada Mountains was not then known. It was thought that a part of that section drained into the Gulf of California and a part into the Bay of San Francisco by the Rio Buenaventura, which had a conspicuous place upon the maps of the period. It was supposed to have its source in the Rocky Mountains and to break through the Sierra Nevadas. To extend the geographical knowledge of this territory was, therefore, the object of this part of the expedition.

The country previously traveled was well known to trappers and traders, and no difficulty was experienced in procuring guides to conduct the party over well-known and, in most instances, well-worn trails or roads The party, which consisted of twenty-five men, was now confronted with a very different undertaking,—viz, the entrance into an unknown country at the beginning of winter, with its attendant hardships and perils. Notwithstanding these conditions, the party left the Dalles in good spirits on the 25th of November, and traveled southward along the east base of the Sierra Nevadas, over a country more or less broken by spurs from the mountains and interspersed with lakes and plains. They suffered considerable hardships from hunger and fatigue occasioned by the scarcity of game and the inclement weather.

They finally reached a point near Lake Tahoe, which they knew from the latitude was nearly as far south as San Francisco Bay. Not having found a river draining westward the chief surmised that the country did not drain into the Pacific Ocean. He then decided to make an effort to cross the Sierra Nevada Mountains to the valleys of California, which his principal guide, Kit Carson, had visited some fifteen years before. This was a hazardous undertaking in the month of February, but the supplies were almost exhausted, and but little hope was entertained of being able to live on the country where they were until spring. The passage of the mountains was therefore undertaken, and made between the 3d and 20th of February, at a point about forty miles south of the pass subsequently used by the Central Pacific Railway. The snow in the mountains was very deep, and it was necessary to beat down a trail with malls to enable the animals to cross at all. After passing the summit they traveled down the middle fork of the American River, and reached Sutter Fort and settlement on the 6th of March, 1844 This fort was about eight miles from the site of the city of Sacramento.

The expedition then proceeded southward through the valley of the San Joaquin, and crossed the mountain at the Tehachapi Pass, thence by the Spanish trail easterly and northeasterly across a barren country to Utah Lake, thence around the southern end of the Uinta Mountains, crossing the Green River and reaching the Platte not far south of the point afterward crossed by the Union Pacific Railway. Thence they traveled up the Platte and through North Park, crossing back to the Pacific slope by what is now known as Arrapahoe Pass, thence through Middle Park and up the Blue River to its source at the Middle Fork, over into South Park, thence to the Arkansaw near Pueblo, where they arrived on the 29th of June. Traveling eastward, they reached their starting point, the mouth of the Kansas, July 31, 1844, having made the entire circuit in almost exactly fourteen months. The party took with them carts as far as the Dalles of the Columbia and a twelve-pound mountain howitzer to a point some distance north of where they crossed the Sierra Nevada, where the howitzer was abandoned because of the difficulty of hauling it over a rugged country devoid of trail and covered with snow.

Considering the character of the country traversed, some of which was entirely unknown, and the difficulties which beset the traveler in a land far from supplies and full of Indians more or less unfriendly, if not actually hostile, this is thought a very remarkable journey, requiring great energy, perseverance and executive ability.

Lieutenant Fremont's expedition of 1845 and 1846 took him to the head of the Arkansaw at the pass which has since borne his name, and which is situated about ten miles from the city of Leadville, thence down the Blue River to Middle Park, westward via the White River to the Green and to Utah Lake, thence to Salt Lake and westward to Humboldt River, making a more extensive survey of the Great Basin as far north as the head water of the Klamath, also in the valleys of California.

On March 3, 1853, Congress passed a resolution authorizing and directing the Secretary of War to make reconnaissances to ascertain the most practicable and economical route for a railway from the Mississippi River to the Pacific Ocean. This work was very thoroughly done by the engineer officers of the army, assisted by civilian engineers, who had had experience in building railways in the Eastern States. They went so far as to make preliminary estimates of the cost of construction based upon these reconnaissances.

The routes examined were those of the 47th to 49th parallel, called the Northern Pacific route, the 41st to 42d parallel, the 38th to 39th parallel, the 35th parallel and the 32d parallel.

The route by the 38th-39th parallel was thought impracticable because of the great elevation of the passes of the Rocky Mountains, and the rough and broken country beyond. Upon all other routes, estimates were made and their advantages and disadvantages set forth in voluminous reports to the War Department. The examination of the route of the 47th-49th parallel was intrusted to Isaac I. Stevens, Governor of Washington Territory, and Lieutenant George B. McClellan, afterward General McClellan, who figured so prominently in the military operations of the first two years of the Civil War.

Governor Stevens's examinations covered all of the territory, excepting that part between Puget Sound and the Columbia River via the passes of the Cascade Range, and, as most of his time and that of his assistants was spent within what are now the boundaries of the State of Montana, the geography of which should be familiar to us all, I shall treat principally of his movements and their results.

No organized exploring party had been through this section of the country since that of Lewis and Clarke, and exact knowledge of its physical characteristics was very meager in the year 1853.

Governor Stevens's principal assistants were Lieutenant John Mullan, Lieutenant A. J. Donaldson, officers of the army, and A. W. Tinkham, F. W. Landor and James Doty, civilian engineers.

The parties were supplied with compasses, odometers and barometers, also astronomical instruments for determining latitude

and longitude. From determinations made with these instruments, maps and profiles were made of the various routes examined, and from these profiles and notes estimates of the cost of wagon roads and of a railroad from St. Paul to Puget Sound were prepared.

Governor Stevens began operations at St. Paul in May, 1853, and by the first of September had reached Fort Benton, the civil engineers having made a reconnaissance thus far, also a superficial survey of the Missouri River. By the 30th of September Governor Stevens and others of his party had reached St. Mary's village in the Bitter Root Valley.

This was made headquarters for the expedition during its stay in this section, which included the remainder of the year 1853 and a part of the year of 1854.

The several parties passed a number of times from Fort Benton to St. Mary's, now known as Stevensville, going via Cadotts and Lewis and Clarke's Pass at the head of the Big Blackfoot, thence down the Big Blackfoot to Hell Gate, near the present site of Missoula, also via two passes at the head of the Little Blackfoot, thence via the Little Blackfoot and Hell Gate Rivers to Hell Gate and Stevensville.

Lieutenant Mullan took a wagon from Fort Benton to Stevensville between the 17th and 30th of March, 1854, traveling via the north bank of the Missouri, the Sun River and the Little Prickly Pear, to the pass at the head of the Little Blackfoot, which was afterward used by the Northern Pacific Railway and which has for many years been known as Mullan's Pass. From this pass he went down the Little Blackfoot by the same route as that taken by the Northern Pacific in 1882.

Lieutenant Mullan's first expedition, that of September, 1853, went south from Fort Benton to a point south of the Musselshell River, thence back to the Musselshell and nearly directly west, crossing the mountains at the same pass.

Mr. A. W. Tinkham made a reconnaissance from Stevensville across to the Flathead, thence by the east shore of Flathead Lake and the Flathead River to Marias Pass and Fort Benton, between the 7th of October and the 1st of November, 1853. His route, from the head of Flathead Lake to the eastern base of the mountains, was practically the same as that taken by the Pacific Extension of the Great Northern Railway in 1892-1893.

The most extensive single expedition from Stevensville as a base was that of Lieutenant Mullan between November 28, 1853, and January 11, 1854. From Stevensville he traveled up the Bitter Root to what is now known as Gibbon's Pass, thence to the Big

Hole Basin and southward to Horse Prairie, which he followed nearly to the Beaver Head, thence by one of its tributaries southward, crossing the main range by the same trail* used by Captain Bonneville in 1833, thence to Fort Hall on the Snake River.

Returning, he came via Market Lake and Beaver Canyon, crossing the main range at the head of Beaver Canyon by the pass now used by the Utah and Northern Railway, thence northward, following almost exactly the route afterward taken by the Utah and Northern Railway to the mouth of the Deer Lodge River. After crossing the pass at the head of Beaver Canyon, he crossed over Red Rock Creek, and, by a low divide, to the waters of what is now called Black Tail Deer Creek, thence to its mouth near the present site of Dillon. With this exception I doubt whether his trail from Market Lake to Garrison was anywhere more than two miles distant from the present line of the Utah and Northern Railway as built in 1881-1882.

A number of routes were examined westward from Stevensville by Governor Stevens himself and several of his assistants. That by way of the Jocho, the Flathead and Clarke's Fork, of Columbia, very nearly followed later by the Northern Pacific, was thought the most feasible and was looked upon with the most favor.

Between November 20 and December 30, 1853, Mr. Tinkham made an examination of the route by the South Nez Perces Trail, afterward known as the Elk City Trail. It goes up the West Fork of the Bitter Root, thence westward across the Bitter Root Range, a very high and broken country, to the mouth of the Clear Water and to Walla Walla.

Lieutenant Mullan passed over what was known as the North Nez Perces Trail, now commonly known as the Lolo Trail, between September 19 and October 2, 1853. He also made an examination up the Flathead Valley via the west side of the lake, up Maple Creek and over on to the Kootenay River in April and May, 1854, returning to Stevensville by a trail lying some fifty miles to the westward. He also crossed over the Bitter Root Mountains via the St. Regis Borgia to Lake Cœur D'Alene, and pronounced it a very excellent route for a wagon road.

The North Nez Perces Trail was traveled by Dr. Evans, United States Geologist for Oregon, in 1850, also by Lewis and Clarke in 1805-1806. Evans and Mullan say it traverses a very rough and rocky country, much broken by spurs and very uneven, the trail lying on the mountain sides much of the way. It is the same as that followed by Chief Joseph with his entire people and all their effects, in their masterly retreat from the United States soldiers in 1877.

*This trail, I judge from the description, lies some thirty miles west of Beaver Canyon.

Lieutenant McClellan's examinations were confined to the territory between the Columbia River near Walla Walla and Puget Sound.

With the exception of a few missionaries in the Flathead and Bitter Root Valleys, there were then no white inhabitants in any part of the territory under examination, which lay east of the west boundary of Montana. The different parties, however, were always supplied with Indian guides who were well acquainted with the country and who seemed to be perfectly willing to impart their information to the whites. In fact, I have seen no mention of the examination of any route where there was not already an Indian trail then in use.

Large numbers of Indians living west of the mountains went to the plains east thereof each year to hunt the buffalo, and occasionally the warlike Crows and Blackfeet crossed to the west side to steal the horses of their more peaceful neighbors. There were, therefore, a great number of excellent trails crossing the mountains, usually by the best passes; in fact, all the principal passes now in use were used then.

The Indians were in all cases peacefully inclined. In all the journals heretofore referred to I saw no mention of actual hostilities worse than the stealing of horses, except in the journals of Bonneville and of Lewis and Clarke. In the latter instance the trouble was occasioned by the killing of a Blackfeet Indian by Captain Lewis near the Falls of Missouri.

During the years 1859-1860 Captain Mullan constructed a wagon road, for military purposes, from Fort Walla Walla to Fort Benton via the St. Regis Borgia, the Bitter Root and Little Blackfoot, crossing the main range at the Mullan Pass, thence via the Little Prickly Pear and Dearborn Rivers to the valley of the Missouri.

The late Colonel Walter W. De Lacy, one of the charter members of this Society, was an assistant to Captain Mullan during the construction of this road. Captain Mullan says, in his report, that the services of Captain De Lacy were especially valuable to him because of the experience which he had obtained in railway construction in the Eastern States.

This military road was 624 miles long, and cost $220,000. Immediately upon its completion the settlement of the State began.

Captain Mullan was the most active of all Governor Stevens's assistants during the period of exploration under his charge, and I cannot close this paper without expressing my admiration for the clear, forcible and elegant style of narrative employed in his reports, and the energy, perseverance and skill displayed by him during his seven years' operations within what are now the boundaries of the State of Montana.

OBITUARY.

James S. B. Hollinshead.

JAMES S. B. HOLLINSHEAD was born in Lexington, Kentucky, in 1869, and died suddenly of heart failure in Butte, Montana, July 19, 1900.

His father was Peter C. Hollinshead, and his mother Elizabeth Mills.

He was their only son, and the last surviving male member, with the exception of an aged uncle, of the Hollinshead family. He received his early education in private schools in Kentucky, but when a youth the family moved to Dayton, Ohio, where he attended the Dayton High School.

In 1886, when seventeen years of age, he entered Lehigh University, Bethlehem, Pennsylvania.

At the completion of his junior year, in 1889, he came to Montana and entered the service of the Montana Central Railway, and was sent to work on the location of the Neihart branch. In the fall of 1890 he returned to Lehigh and completed his course, graduating the following year, taking the degrees of Bachelor of Science and Mining Engineer. He was fourth in his class, and that entitled him to membership in the honorary society of San Beta Delta of that university. While in college he worked during the vacations and improved every opportunity to obtain remunerative employment, and with the money thus earned paid his way through college. He returned to Helena, Montana, in the summer of 1891, and again entered the employ of the Montana Central Railway. He was with them but a short time when he entered the service of the Drum Lummond Company, at Marysville, under Mr. John Herron, who is well known to the Montana Society of Engineers.

In the fall of 1892 or spring of 1893 he entered the employ of the Boston and Montana C. C. and S. Mfg. Co., at Great Falls.

He occupied various positions while in their employ,—as foreman on the gas producing during the trying days of developing the production of gas from Sand Coulee coals; foreman on the blast furnaces and reverberatories, and general night foreman over the whole smelter.

This position was rather severe on his health, and after several periods of sickness he removed to Butte in February, 1897, and was

mining engineer for the Butte and Boston Con. Mfg. Co. until January, 1900, when he resigned to open up a private office. After a few months' work he again entered the employ of the Boston and Montana C. C. and S. Mfg. Co. as engineer in charge of their interests in the disputed territory that was in litigation between them and the Montana Ore Purchasing Company, and was engaged in this work until the time of his sudden death.

He was of a very enthusiastic temperament, and whatever he undertook to do was vigorously pushed to a successful termination. He was a devoted member of the Protestant Episcopal Church, having been vestryman in the various churches in the cities where he resided. He was always interested in the moral and religious welfare of the community in which he lived, and many are the men that have been assisted in their hour of need by his timely generosity.

He was a devoted son and the trusted support and counsel of his family during the lingering illness of his father in the later years of his life.

In July, 1898, he was married to Daisy Evans, the daughter of Mr. and Mrs. W. J. Evans, of Great Falls.

His domestic life was happy, hospitable and congenial, and his whole ambition was to provide comfort and happiness to those who were dependent upon him. His mother and sister were living with him at the time of his death. By his manly character and genial disposition he made many friends wherever he resided, and his untimely death was deplored by all who had ever known him.

He was always interested in the welfare of the Montana Society of Engineers, having been a member of the Society for several years, and was one of our most respected and promising members. He had made application to become a member of the American Society of Civil Engineers, but died before the final papers were made out.

The following resolutions were adopted:

Whereas, The Creator and Ruler of the Universe, in His infinite wisdom, has taken away from the Montana Society of Engineers one of its most devoted members, James S. B. Hollinshead; and

Whereas, The high esteem with which he was regarded by his associates in the Society, impels us to express in our records the deep regret we feel over his decease; therefore,

Resolved, That we extend to the wife, the mother and the sister our heartfelt sympathy, and assure them that of him there shall always remain a cherished memory by this Society. In his honesty and zeal he was reaping an ideal return for faithful endeavor when his promising career was ended.

Resolved, That the minutes of the Montana Society of Engineers shall contain the words above written, and that a copy be sent to the relatives of the deceased.

C. H. Repath,
C. W. Goodale, } *Committee.*
C. H. Moore,

Henry M. Claflen.

The Civil Engineers' Club of Cleveland, at the very opening of the new century, is bereft of one of its oldest and most respected members. Mr. Henry M. Claflen passed away after a lingering illness at an early hour New Year's morning, January 1, 1901, in his sixty-sixth year. He was born in 1835 at Attleboro, Mass., was of Scotch and Puritan descent, and in 1852 came to Cleveland with his uncle, Peter Thacher, of the firm of Thacher, Bent & Co., to engage in bridge building, an industry with which his name has remained inseparably connected. Wooden bridges were then in vogue, and the firm acquired a wide reputation in their construction.

During a part of the Civil War Mr. Claflen was employed by the Governm[illegible]n expert, to superintend the rebuilding of railway bri[illegible] by Confederates in Tennessee and Kentuck[illegible] attended with many difficulties and dangers, wh[illegible] he accomplished with success, greatly facilitating [illegible]ments of the Union Army.

At the close of the war Mr. Claflen returned to Cleveland, and, organizing the bridge-building firm of McNairy, Claflen & Co., became its president, and conducted for years a large and successful business. The firm built a large number of bridges, of which the iron portion of the Superior Street Viaduct in this city is a monumental example. The concern was also engaged in car building on an extensive scale.

Mr. Claflen afterward organized the Claflen Paving and Construction Co., of which he was president, taking large contracts for the paving of the principal thoroughfares of Cleveland as well as in other cities. These pavements were usually of wood in the first instance, but as the material wore out stone was substituted. Both these companies accumulated large sums of money, though later, through unfortunate contracts, large amounts were lost. Mr. Claflen at one time was reputed to be quite wealthy, yet owing to a series of misfortunes, without fault on his part, he ended his life a poor man. For the last few weeks he was cared for at St. Vincent's Hospital.

It is doubly lamentable that a man of such ability and integrity, and unwearied devotion to business, having reached an age when he might justly expect to settle down in the comfortable enjoyment of his property, should find both property and life forsaking him.

Mr. Claflen was married in 1863 to Miss Alice B. Hall, daughter of John Hall, of Toronto, Canada, who survives him. They had one son, who died young. His brother, Mr. Harvey T. Claflen, constructing engineer at the Variety Iron Works, and his family are the only remaining relatives in Cleveland.

Henry M. Claflen was a charter member of this Club, and always took a deep interest in its welfare, subscribing liberally to its funds and assisting on social occasions. His genial and happy disposition made him a welcome companion, while his upright character and refinement of manner won him the admiration of all.

In closing this sketch your committee would offer the following:

Resolved, That in the death of Henry M. Claflen the Civil Engineers' Club of Cleveland has lost a member who, since its organization, has honored it with his name, his influence and his character.

Resolved, That this memoir be spread upon the minutes of the Club, and published in the JOURNAL.

Resolved, That a copy of the same, with the condolence of the Club, be transmitted to the widow of the deceased.

FRANK C. OSBORN,
WM. H. SEARLES,
Committee.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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INSTALLATION, OPERATION AND ECONOMY OF STORAGE BATTERIES.

BY ERNEST LUNN, MEMBER DETROIT ENGINEERING SOCIETY.

[Read before the Society, February 28, 1901.*]

WHERE the conditions are such that the demand on the central station is ever fluctuating and reaches a maximum in the winter time of three or four times the average load for only an hour or an hour and a half a day, which is the case in nearly all cities of the size of Detroit, a storage battery plant is a very valuable auxiliary.

This paper will deal with the battery plant of the Edison Illuminating Company, of Detroit, Mich., but before taking up that subject I wish to give a short description of the cell most commonly used in lighting and power stations.

There are several forms of cell, but all in commercial use are of lead plates in dilute sulphuric acid, and depend for their action on the formation of lead peroxide on the so-called positive plate and of sponge lead on the negative when a current is forced through the cell; which formations are reduced again, with production of a current in the reverse direction, as soon as the cell is free to discharge. The typical cell is merely two plates of pure lead in dilute acid. In practice the formations are facilitated by previous mechanical or chemical preparation of the plates. The mechanical preparation may be the slitting or grooving of the plates, to facilitate the electrical action by exposing more of the metal to the acid; but it is more often a careful determination of the plate structure, so as to secure and maintain the mechanical integrity.

*Manuscript received April 4, 1901.—Secretary, Ass'n of Eng. Socs.

The chemical preparations are usually lead oxides or salts as part of the first construction, so that the work remaining to be done by the earlier electrical charges may be a minimum.

It should be noted that there is no electrical storage in a so-called storage battery or accumulator. The storage is of chemical energy, as in any electrical battery cell, and the difference between a common chemical battery and an accumulator is that in the latter the chemicals used permit a reversible cycle, the electric discharge being followed by an electric charge, which restores, with more or less completeness, the chemical energy which gave the discharge.

The chemical actions involved in the process of discharging and charging are very complicated, and have not been positively determined. The commonly accepted theory is that, on discharge, the lead peroxide on the positive plate is reduced to lead sulphate, while at the same time the sponge lead on the negative is sulphated, with the result that the sulphur radical is abstracted from the electrolyte, leaving it more dilute, hence of lower specific gravity.

A reversal of conditions takes place during the charging process. Oxygen and hydrogen are liberated by the electrolytic action of the current, which is forced through the cell in opposite direction to that of the discharging current. Oxygen unites with the sulphate of the positive plate, converting it into lead peroxide and liberating the sulphur radical, which goes back to the electrolyte, increasing its specific gravity. Hydrogen is freed at the negative plate, and decomposes the sulphate of lead on that electrode, reducing it to pure lead. The sulphur returns to the electrolyte, further increasing its specific gravity.

An accumulator cell consists of three parts: the tanks, the plates and the electrolyte surrounding them. The retaining tanks for large batteries are usually of heavy ash, lined on the inside with pure sheet lead; while those used in small cells are of either hard rubber or glass. The Manchester positive* plate, made by the Electric Storage Battery Company, of Philadelphia, has a framework of lead alloy, containing a series of buttons. The framework gives conductivity and strength to the plate, holds the buttons in place and is continuous with the lug to which the bus bar is connected.

The buttons, upon the surface of which is found the active material, are made of lead ribbons about 9 inches long and $\frac{1}{2}$ inch wide, corrugated on one side and rolled up, making them about $\frac{3}{4}$ inch in diameter. These are put into holes in the alloy frame,

*The terms positive and negative apply to the terminals of a battery exactly the same as we apply them to the terminals of a dynamo.

which they just fit, and hydraulic pressure is brought to bear upon them, which, with the subsequent forming process, causes them to swell so that they fit firmly in their positions.

The special advantages of this button construction are that it is free from buckling caused by the unequal expansion of active material, and also that it exposes a very large surface to the action of the electrolyte. Its spiral formation permits the attainment of both these desirable qualities. Other batteries have differently formed plates, but all manufacturers endeavor to make a plate which will expose a large surface of active material to the electrolyte and which will be free from danger of scale and metal short-circuiting the cell internally, and at the same time be durable and free from buckling.

As nearly as may be, the negative plate is of pure lead, but in an allotropic state. Its construction is somewhat different than that of the positive plate, although a few years ago both plates were formed in a similar manner and like the present negative. The essential qualities of a good negative plate are that it shall have good conductivity and a framework strong enough to hold in place the active material which must compose a greater part of the plate. In the chloride plate a compound containing lead chloride is formed into tablets about $\frac{3}{4}$ inch square and $\frac{1}{4}$ inch thick. These squares are placed in a mold, and a grid of nearly pure lead is cast around under hydraulic pressure, leaving them about $\frac{1}{4}$ inch apart. They are intended to be as close together as the mechanical construction of the plate will allow. After casting, the plates are subjected to an electro-chemical reduction process, which removes the chlorine from the tablets and leaves them in the form of spongy lead, chemically pure and very porous.

A good positive plate must have ample surface over which the active material may spread, while it is essential that the negative be porous enough to allow a rapid diffusion or circulation of the acid as it comes in contact with the lead particles, not merely on the surface, but throughout the mass. On this quality depends to a great extent the maximum rate of charge and discharge. If a particle of lead, after being partially sulphated, is surrounded by a dilute solution of sulphuric acid, having a high resistance and low specific gravity, it is practically incapable of adding any energy to the circuit of which it is a part until a stronger (and hence lower resistance) solution of acid has come in contact with it. At any given rate of discharge, the attainment of this state of helplessness on the part of the particles composing the negative plates is the working limit.

A short rest, or a lower rate of discharge, will allow the cell to regain the normal voltage corresponding to the amount of active material left unacted upon in the plates. It will thus be seen that the freedom with which the electrolyte may diffuse in the plates decides the question of the maximum charge and discharge rates of the battery.

An ideal battery would be one which gave up the same number of ampère hours whether discharged at a high or at a low rate. In central station work, where the load is fluctuating, and especially where there is a very decided peak for a short time,—say for one hour,—it is the battery with sufficient capacity to carry that peak that is wanted; and yet in the accumulator of to-day the total capacity at the one-hour rate is only half what it is at the eight-hour rate, and only a few years ago the maximum was very little over the eight-hour rate.

The voltage, on open circuit between the positive and negative plates of a cell, ranges from 2 to 2.2 volts. This variation depends upon the type of cell and upon the state of charge. As soon as discharge begins the pressure drops, and it continues to drop until the limiting point is reached, which is about 1.7 volts. This lower limit coincides with the reduction of all the available active material. The reaching of this limit, as already noted, does not prove that there is no more active material left in the plates, but only that there is none in working contact with the electrolyte. Sometimes a series of cells may have an average voltage less than 1.7, which means that some cells are useless and are being charged by the current forced through them by the others in the series.

The electrolyte is dilute sulphuric acid, 28 per cent. by bulk. Both acid and water must be chemically pure. The impurities most to be avoided are those which affect the chemical reactions in the plates, the metals being particularly objectionable. The acids other than sulphuric which are present in commercial sulphuric acid—*i.e.,* nitric and hydrochloric acid—are likewise to be avoided. There is evaporation of water from the surface of the electrolyte, and there is a loss of fluid by spraying during the latter part of charge. These losses have to be made good by the addition of pure water and new electrolyte. A still for water distillation is a common annex to a large battery. The loss of acid is usually negligible.

Setting Up. In setting up a battery, the positive plates of one cell are connected to a lead bus bar, on the opposite side of which are connected the negatives of the next cell.

Fig. 1 shows the arrangement of plates and bus bar connections. At present the plates occupy only one-half of the available

space in the tanks. The battery will be completed as the demand for service requires increased capacity.

Connection to System. In connecting the battery to the system, three methods may be followed, according to the manner in which the battery is operated.

In railway work, and particularly in suburban lines when the potential of the system is extremely variable, the battery is connected in multiple with the system. It discharges when there is a drop in voltage caused by a heavy demand for current, and receives its charge when the voltage rises above the normal pressure of the

FIG. 1. STORAGE BATTERY TANKS.

system. At all other times it is allowed to float, neither charging nor discharging. A cable connection is usually made to a generator, so that an occasional charge may be given it if necessity demands. No other regulating apparatus is required. A battery connected in this manner is used simply to equalize the pressure on the system, and does not sustain any regular charge and discharge.

In street railway systems, where the battery is used not only to equalize the pressure, but to carry regular peaks, special apparatus for charging and discharging must be provided. The apparatus used for this purpose is called a "booster." A booster is simply a motor-driven generator in series with the battery circuit. When a

charge is given the battery the booster raises the pressure at the terminals of the accumulator sufficiently to force through it the desired amount of charging current. On discharge it has a reverse action, and lowers the pressure over the battery until the desired discharging current is obtained. The booster commonly used in railway operation is a "differential booster," so called because it has a differential winding which permits the charge and discharge to be governed automatically.

In a lighting system, where the pressure must be kept much more constant than in railway work, the regulation is controlled by a series of end-cells connected to end-cell switches, together with a booster. The booster may be used for either charging or discharging, but has no automatic controlling arrangement. It is customary to use the booster only on charge. The discharge is controlled by the end-cell switches.

The so-called "end-cells" are merely a certain number of the terminal cells of the battery, so arranged that any number of them may be successively connected in series with the main battery as the load increases and cut out again as the load drops off.

The number of end-cells, as well as the number in the main battery, depends upon the voltage at which the system is operated. The maximum voltage of the main battery must equal the normal voltage of the system. There must be a sufficient number of end-cells to insure proper regulation under all conditions of charge, and also to provide for the distribution drop of the system. For instance, in a 125-volt system this would mean fifty cells in the main battery and about thirty additional end-cells to give a bus bar voltage of 136 at end of discharge. From the cell bus bars between the end-cells copper leads are run to the end-cell switches, terminating in a series of studs arranged in succession. Parallel to these studs is a copper slide, from which connection is made to the switchboard. A laminated copper brush, making sliding contact with the slide, is moved successively over the studs by means of a screw propelled either by hand or by a motor.

Fig. 2 shows one of the end-cell switches, showing the arrangement of the copper slide and studs.

The operation of the battery is very simple. In the Edison system, for instance, the pressure across the mains is about 120 volts. In order to balance the battery against this pressure it will be necessary to have about 60 cells in series, counting two volts per cell. In this condition it acts as a regulator, or floats; for if there is a rise of pressure on the mains, due to a sudden cessation in the demand for current, the battery will absorb the surplus energy by

suffering a slight charge; while, on the other hand, should the pressure suddenly fall, the battery discharges enough to keep the voltage almost constant in the system.

In street railway work, where the load is much more fluctuating than in lighting, this characteristic of the battery is of great consequence.

As the cells discharge, additional cells have to be added, in series with those already in, in order to keep the pressure constantly 120 volts at the service ends of the mains. This is done by moving the sliding contact brush further along the end-cell switch. As the

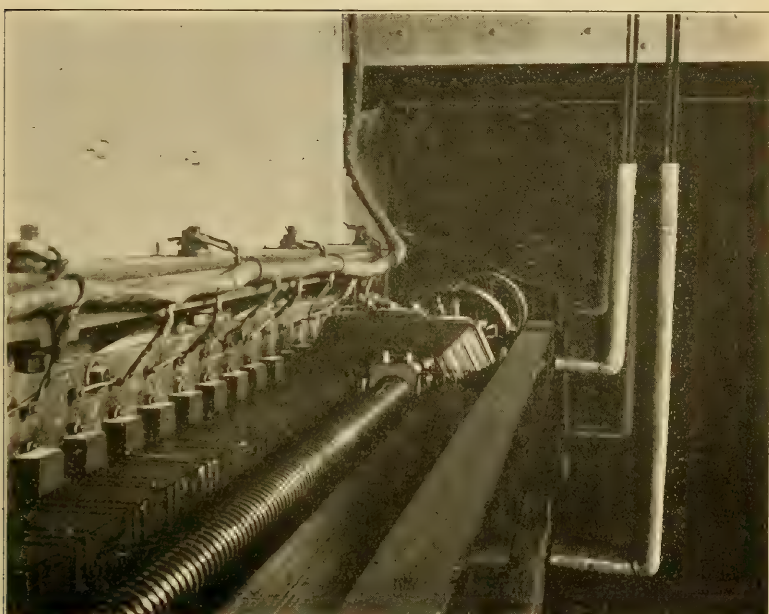


FIG. 2. END CELL SWITCH.

load drops off, these cells, previously cut in, have to be cut out again. This is done by moving the brush in the opposite direction. The end-cell switches are operated from the switchboard, so that the operator has complete control of the battery from his position at the board.

Availability. In order that the effect of the Edison battery may be easily understood, I wish to say a word concerning the general plan of the Edison Illuminating Company's underground distribution system. This will be necessary because the battery plant is now a part of that system, and its value can better be

appreciated when the conditions of the field previous to the installation of the battery are understood.

The main station (Station "A," corner of State street and Washington avenue) has been, and is at present, the generating plant for nearly all the current used in the underground system.

Fig. 3 is a diagram showing the relative positions of this station and the centers of distribution of the underground system within the half-mile circle; also the location of the battery station, Station "E."

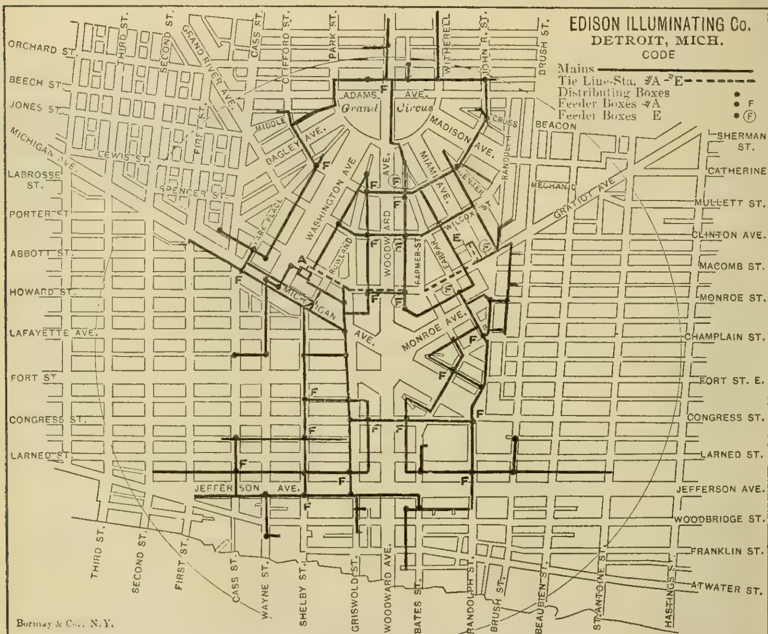


FIG. 3. PLAN OF COMPANY'S SYSTEM.

Last spring the Edison Illuminating Company was facing the proposition of determining the most economical way to increase the output of the generating station. It was estimated that the holiday season load would run about 4000 or 5000 ampères, or 500 to 600 kilowatts, higher than the year before; and in the previous year the station was loaded to its full capacity. Owing to the already crowded condition of Station A, the cost of installing generating machinery sufficient to supply the demand for the coming year, with some facilities for taking care of the probable increase of load of the following season, would, it was figured, be greater than the cost of an accumulator plant.

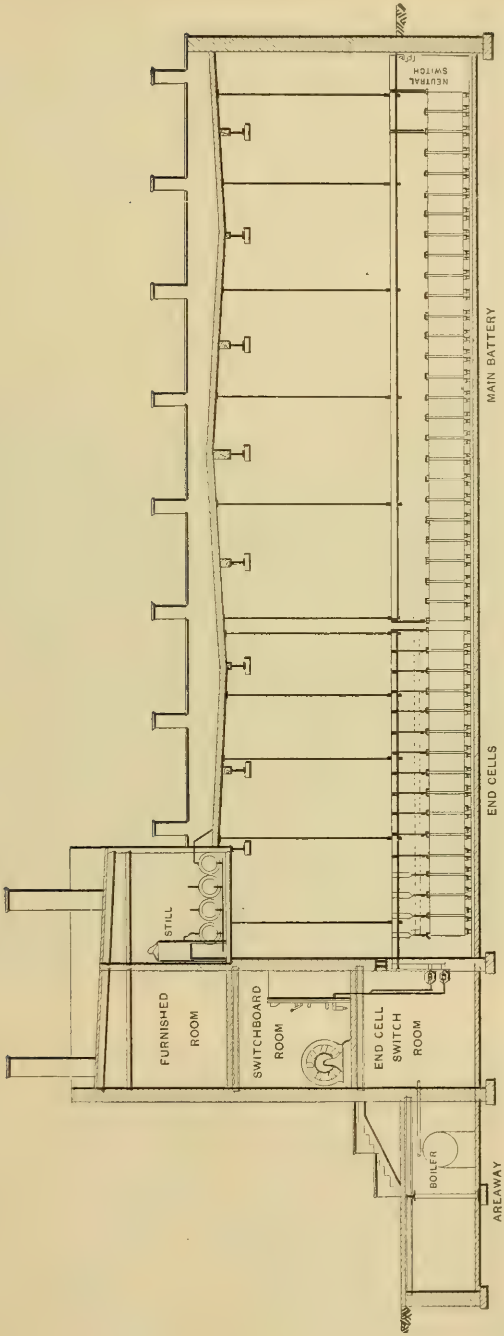


FIG. 4. SECTION OF STATION.

Furthermore, it was not only undesirable, but next to impossible, to increase sufficiently the output of Station A.

A converter station, taking power from our alternating system, and situated where the battery, Station E, now is, would have been a possible expedient had it not been for the fact that the peaks, on both the Edison and the alternating stations, take place about the same time. The additional equipment necessary to insure service equal to that given by the battery would have cost more than the battery. The peak, which comes only in the winter months, lasts, all told, not more than 125 hours per year; and to install generating machinery to carry that load for that length of time, and to lie practically idle the remainder of the year, would mean an expenditure of money difficult to realize encouraging dividends on. With a storage battery plant it is different; it takes the high peak in the winter months and furnishes the system with sufficient reserve at all times, while at the same time it allows two-thirds of its capacity to be used at will every day in the year. Whatever the advantages afforded by the battery, they are felt every day. Fewer boilers have to be kept fired up and fewer engines ready to run, and the generating machinery can be worked at the point of greatest economy.

Location. The decision to install a battery led to the investigation of possible sites. A theoretical location could have been easily determined by taking into account the existing conditions and the possible extension of the system had not other conditions introduced very important limiting factors. These factors included the available sites, their comparative cost and the comparative cost of copper necessary to make the best connection to the system, besides the fire risk to which the location of each would subject the battery plant.

Construction of Building. The lot selected gave no excess of space. The sectional elevation of the battery station shows this (see Fig. 4).

To get the battery in place without crowding, and with convenient arrangement of copper, required considerable study. The final copper plan was drawn by the battery company after the dimensions of the room were fixed by us, and the copper and switches were got out according to this approved plan while the building was in progress. Work was begun on the foundation May 1, 1900, and the building was finished in August.

The wall above the opening for the end-cell switches is of brick, clear through to the roof, thus separating the battery room from the rooms in front. There are good reasons for having it

so arranged, the principal one being that it protects the cells from fire originating in the dwelling rooms. Fire is not likely to originate elsewhere. The switchboard and booster room is directly above the end-cell switch room. All the operating is done from this room.

To go back to the construction of the building. It is absolutely necessary that there be a good foundation, for there are 160 tanks, weighing about 2 tons apiece, in a room 30 x 85 feet. These must be kept in perfect alignment, and any sinking or failing in the foundation would cause serious trouble. The natural foundation

FIG. 5. STATION E.

was found to be of clay. A good system of drainage was put in the ground, so that the tile came under the walks between the tanks, and then a covering of concrete 16 inches thick was spread on, coarse at the bottom and finer at the top. This used up the material of the building found on the lot. Upon this were placed extra heavy paving bricks. It took eight barrels of pitch, between the bricks, to complete the foundation, which, when it was done and dry, was perfectly level and also a good insulator. One fails to detect the slightest sign of a current when standing on the floor and feeling at the same time any of the live conductors. (Those

who are accustomed to getting a poke every time they lay a hand on a wire around a station will appreciate the convenience of having a non-conducting floor.)

The side walls are of red pressed and partially vitrified brick to a height of about 9 feet above the floor, continuing the rest of the way of ordinary building brick. This pressed brick is acid-proof. The front is of gray pressed brick, and so designed as to give the building the appearance of a dwelling house rather than that of an electric lighting station. (See Fig. 5.)

Installing the Battery. The setting of the tanks was an operation requiring great care. On account of their weight, they must be well supported. Insulation, too, is a matter of great importance. Each tank is supported on eight petticoated insulators,

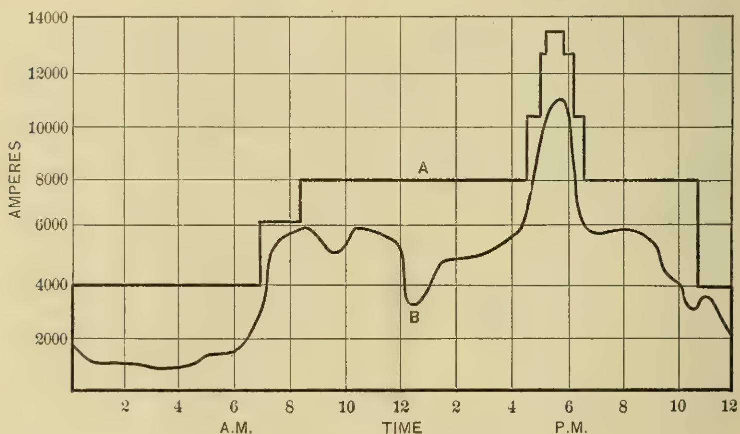


Fig. 6. Load Curve.

Thursday, January 25, 1900. Storage battery not installed.

which rest on vitrified tile 7 inches wide and $\frac{7}{8}$ inch thick, set to a templet and on sulphur. With the tile set and the porcelain insulators fastened to the bottoms of the tanks by being stuck into their places with hot pitch, the operation of tank setting became both simple and rapid. As soon as a few tanks were put in place, the glass supporting plates were put in, and the battery plates supported on these. In this way a large force of men was kept at work. Different gangs were setting tile and tanks, and cleaning up plates and putting them in place in the tanks at the same time. As soon as it could be done, the work of burning the plates to the lead bus bar was commenced.

Burning is necessary instead of the more convenient soldering, because solder would be promptly attacked by the acid spray.

Perhaps the most interesting of all the work was filling the tanks with the acid. At the rear of the building was placed a tank similar to one of those used for the battery, and about 8 feet above them. Ten rubber tubes (garden hose) were constantly siphoning the acid from the tank to the battery tanks. A gang of men was emptying carboys into the upper tank as fast as they could be handled. A carboy would be tipped upside down over the tank, the box surrounding it supporting it in such a way that its neck extended into the tank about 5 inches. The acid in the tanks could therefore never get above the level of the mouth of the carboy as it was thus inverted. As soon as one was placed on the tank and

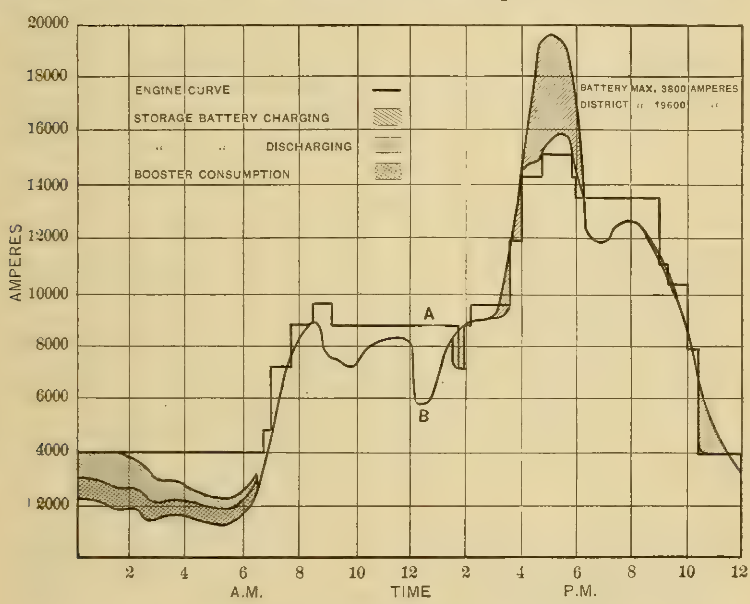


FIG. 7. LOAD CURVE.

Tuesday, December 18, 1900. Storage battery installed.

started to empty, it was shoved along to make room for another, and was empty by the time two others had been put on behind it. The process was very rapid, and over 2000 carboys were emptied in about a day and a half. Everything had to be so far completed by the time the acid was in that the first charge could begin immediately afterward, for it injures the plates to allow them to stand in the electrolyte for any length of time in an uncharged condition. The injury is in the formation of an irreducible sulphate.

The first charge was begun immediately and continued for thirty hours, the rate being comparatively low,—500 ampères to start with and increased later to 700 ampères. The cells were over-

charged on the first occasion and on the next few charges, the object being to complete the formation of the active material, which is nearly, but not quite, completed when the plates leave the factory.

Operation. The subject of operation can best be understood by an inspection of the following curves:

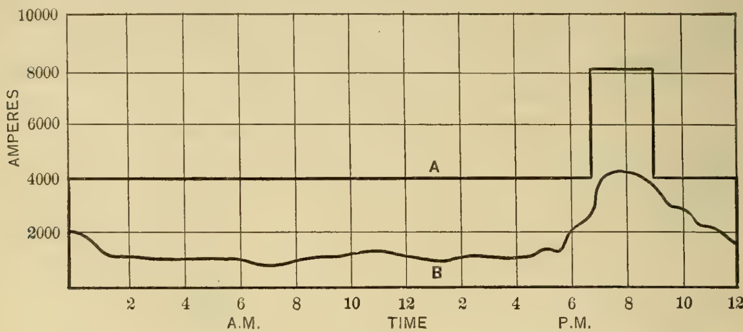


Fig. 8.

Sunday, September 23, 1900. Storage battery not installed.

Fig. 6 shows a characteristic load curve previous to the installation of the battery.

Line A, called the engine curve, represents the normal rating of the units running. Line B, called the commercial load curve, represents the ampères supplied to the system.

It will be noticed that the load factor of the engines' run—that is, the ratio of the ordinates of curves B to A—is compara-

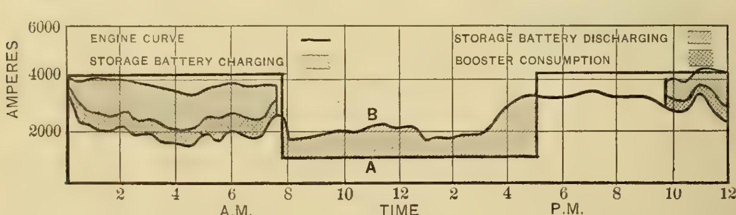


Fig. 9. Load Curve.

Sunday, November 25, 1900. Storage battery installed.

tively low. It was necessary to run the engines at this low load factor in order to secure reliable service under all conditions of operation.

Fig. 7 illustrates a characteristic load curve after the battery was installed. The cross-hatched areas represent the operation of the battery. It will be noticed that the load factor has been greatly increased. This is due to the fact that the battery was on the system and supplied a reserve, making it unnecessary to run gen-

erating machinery below the normal rating, as was done before the battery was installed.

Figs. 8 and 9 are characteristic Sunday load curves, before and after the battery was installed respectively. Compare again the load factors in the two cases.

Fig. 10 shows the operation of the battery in emergency cases. On account of a feed-water pipe bursting at the generating station, the plant was shut down for about three-quarters of an hour, while the battery carried the entire district load, giving the engineers sufficient time to get another boiler unit in commission.

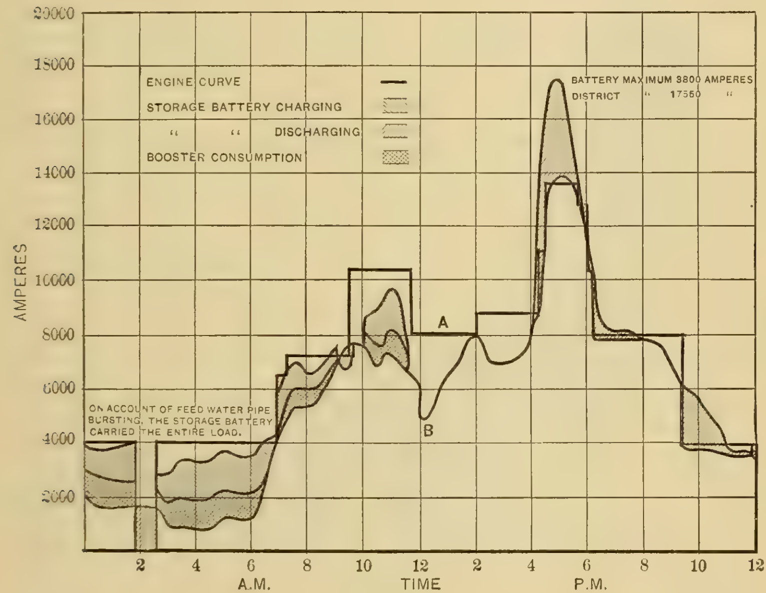


FIG. 10. LOAD CURVE.

Wednesday, November 21, 1900. Storage battery installed.

Fig. 11. Curve O O O is the battery capacity curve, made up from data furnished by the Electric Storage Battery Company. The discharge rates are plotted as ordinates; the time and hours as abscissas, the capacity being 2750 ampère hours at the one-hour discharge rate, 3750 at the two and one-half, 4350 at the three and 5440 ampère hours at the eight-hour rate.

Curves A A A, B B B, etc., are curves showing the various discharges in ampère hours, plotted in a similar manner to the capacity curve.

It is well known that the available capacity of a battery increases as the rate of discharge decreases, and it was for the pur-

pose of showing the relation existing between them that the capacity curve was superposed on the discharge curves.

Suppose at any particular time it is known that, say, 2500 ampère hours have been taken from the battery at various rates of discharge, and it is desired to know how long a certain discharge rate, say 2000 ampères, can be carried. Follow up the 2500-ampère discharge curve until it intersects the 2000-ampère rate line. The distance between this point of intersection and the point where the 2000-ampère rate line cuts the capacity curve represents the length of time that 2000 ampères can be carried, which is about

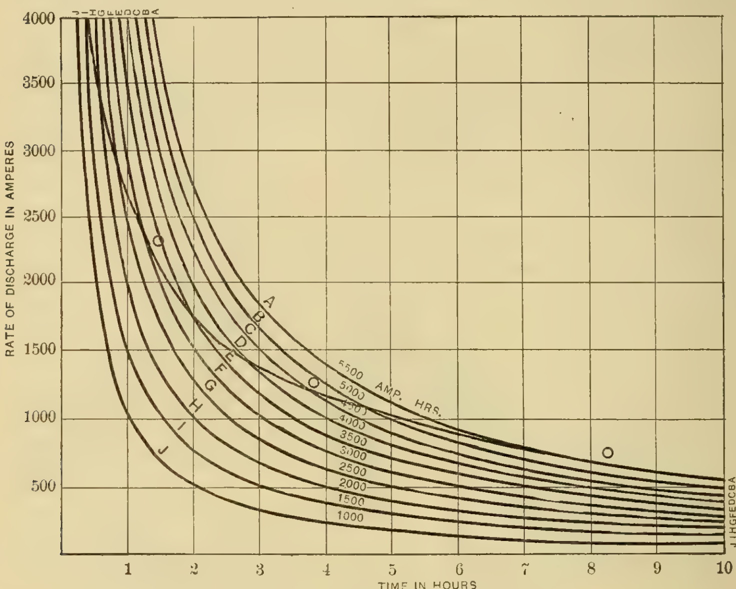


Fig. 11. Battery Curves.

Capacity curve shows capacity of battery at different rates of discharge. Discharge curves show various discharges in ampère hours and their relation to the capacity curve.

twenty minutes. With the battery in the same condition, 1500 ampères could be carried for about forty-five minutes, as shown by the distance between the points of intersection of the 1500-ampère rate line with the 2500-ampère discharge curve and the capacity curve.

In a similar manner, it can easily be calculated how long any rate can be carried by the battery, or whether it can be carried at all, if the ampère hours previously taken out are known.

It is not customary to work the battery near enough to its limit to make it necessary to consult the curves. It is, however, very

valuable in emergency cases to know how long a certain rate can be carried. The curves have been repeatedly found to be very reliable, and to know just how long the battery can be depended upon to carry a given load, if necessity demands, is a source of no small satisfaction to the operator.

Economy.—The real economy of an accumulator plant is hard to determine, constituting as it does only a small part of a large system, each department of which adds to or detracts from the economic operation of the whole, according to the degree of efficiency with which each branch is run. It would be unfair to expect the number of pounds of coal burned per kilowatt-hour output to be greatly decreased on account of having the battery in operation when it is remembered that only about 8 per cent. of the output is dealt with by the battery. It has been impossible to get accurate data on this point. There has been a falling off in the amount of coal burned for a given output since the battery was installed, but I am not prepared to say that the saving in the coal bills, calculated along that line, is more than enough to pay the operating expenses of the battery station.

I do hold, however, that the cost of operating and maintaining an accumulator plant (the one under consideration in particular) is no greater than that of a complete generating plant of the same capacity, and in the above-mentioned case the cost of installation of such a plant would have been in excess of the first cost of the battery. In such a steam plant we would not have expected any greater reduction in the cost of coal per kilowatt-hour than we have already experienced while using the battery. There are other reasons, however, for believing that the installation of the battery plant was a wise move. Situated as it is, it makes it possible to cover districts which could not be reached directly from Station A. Not only that, but the whole system feels the effect of the better regulation afforded by the battery. It acts as a reservoir, ready at all times to give energy to the system, and forestalling any drop in pressure which could be caused by the failure of any single unit at the generating station. It is customary to keep always enough reserve energy in the battery to carry for about an hour the load dropped by such an accident, giving the engineers plenty of time to get another set of generators or boiler plant in commission. This reserve amounts to about one-third of the capacity of the battery. We are at liberty then to use the other two-thirds in whatever way good operation demands.

So far the battery has given the best of satisfaction. During the summer months we expect to use it to as great an advantage as

during the past winter. Thunder-storm peaks can be taken care of without the necessity of keeping boilers in readiness for such an emergency, and the load factor of the engines run can be raised to the most economical point of operation, reducing by no small amount the number of pounds of coal burned per given output. As a means by which the output of the system could be increased the battery was the cheapest and best; and as for supplying reserve, ready at a moment's notice, it has no equal. Its many other virtues only strengthen an ever-growing respect for it.

CONCRETE CONSTRUCTION.

By C. R. Neher.

[Read before the Engineers' Society of Western New York, March 5, 1901.*]

The object of the present paper on concrete construction is to give a few practical suggestions based on actual experience. I have no new theories to advance, but am a believer in the use of a wet mixture, of such proportions as to give a maximum of strength under compression, always using Portland cement. Where economy is necessary, I would introduce large stone in the heart of the mass, or cellular construction, but would not cheapen the concrete.

My remarks will be from the standpoint of the purchaser and contractor, as well as the engineer. As engineers, in our desire to secure good work and uniform results, we are apt to introduce unnecessary refinements, resulting in increased cost, retarding the progress of the work and often defeating the end in view.

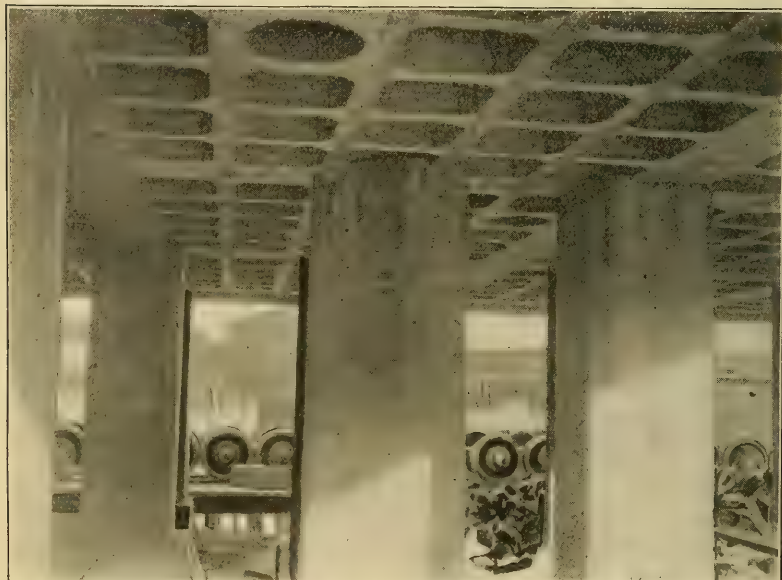
As concrete is almost always used in compression, I would recognize no test but that of the actual mixture to be used in the work and that under compression. Such a test demonstrates the excellence of all the ingredients and whether they are properly proportioned. Even with excellent ingredients, low results are often obtained by reason of wrong proportions. To illustrate, last summer I had occasion to test the value of copper slag and lake gravel in concrete. The gravel alone, mixed five parts gravel to one of cement, was good for about 60 tons per square foot ultimate compression after seven days. The standard of excellence desired was that obtained by limestone and gravel, mixed 1 cubic foot of cement to $2\frac{3}{4}$ cubic feet limestone (passing a 2-inch ring, pieces $\frac{1}{2}$ inch and under excluded) and $2\frac{1}{4}$ cubic feet of lake gravel, which gave an average ultimate compression in seven days of 135 tons per square foot.

My first tests on the slag mixture gave only about 80 tons per square foot in seven days, and appeared to demonstrate a low value for the slag; but examination of the fracture showed an excess of gravel and a fracture through the spaces where the most gravel existed. A slight diminution in the quantity of the gravel gave results of over 140 tons in seven days. The copper slag is shown by analysis to be free from deleterious chemicals, except lime, and its use in work of four years' standing seems to prove the absence of free lime. The slag can be obtained cheaper per cubic yard than

*Manuscript received April 23, 1901.—Secretary, Ass'n of Eng. Socs.

stone, but, by reason of its great weight (about 3300 pounds per cubic yard for run of crusher, against 2800 pounds for limestone), the cost of transportation and handling is increased. Owing to its weight and abrasive qualities, the duty is harder on the mechanical mixer and tools, and the slag is more apt than limestone to separate itself from the other ingredients when thrown from a height or used with a large amount of water; and its apparent economy is largely offset by the objections mentioned.

The engineer should seek to obtain greatest strength, complete filling of voids and a smooth exterior; all of which can be obtained



Under Section of Floor, Eastern Elevator, Showing Beams and Girders. Ransome Concrete Construction.

by simple means. An excess of fine material, while producing a good finish, weakens the concrete; imperfect filling of voids produces rough work, and is also an element of weakness; therefore, to define the exact proportions to be used in any piece of work necessitates an intimate knowledge of the exact materials that will be used by the contractor to whom the work is awarded. As stone from different quarries does not produce the same fracture or the same amount of fine material, it is seldom wise to state the exact proportions, except that of the cement to the rest of the aggregate, the remaining ingredients to be so proportioned as to fill all voids without an excess of fine material, leaving the exact amounts to be

determined by experiment with the actual materials to be used when placed on the work.

Specifications should state the minimum size of broken stone allowed, as well as the maximum, as broken stone is graded in five commercial sizes; and to determine the voids it is necessary to know the sizes included in the coarse aggregate. As a measure of economy, it is well to specify run of crusher, dust removed. This is usually sold at 5 per cent. less than the graded sizes, and contains about 20 per cent. more material, leaving less fine material to be supplied to fill voids, resulting in a saving of 25 per cent., which

Thirty-six-inch Floor, Eastern Elevator, Buffalo, N. Y. Ransome Concrete Construction.

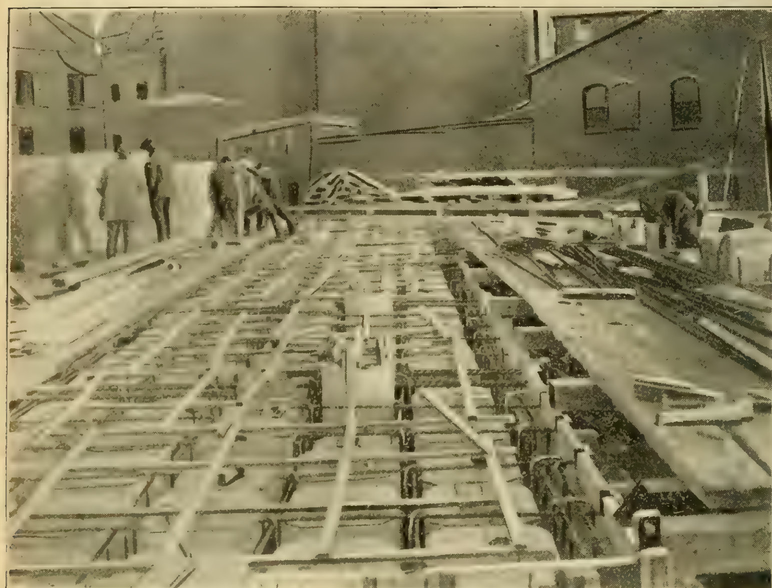
will be offset somewhat by greater cost per cubic yard for transportation.

Thorough ramming should always be specified. The general impression among men employed in placing concrete is that little ramming is required if the mixture is wet. This is a mistake. Large voids will show in the face of the work if not thoroughly tamped; and the fact that wet mixtures are seldom tamped enough is one of the reasons why it sometimes does not show up so well in testing as compared with dry mixing, which must necessarily be thoroughly tamped.

Thorough mixing should also be insisted on, and on all work

where an amount to exceed 40 cubic yards per day is placed mechanical means should be used. In this way greater strength and uniformity can be obtained at less expense than by the addition of cement.

A concrete composed separately of several of the commercial sizes of broken stone, gravel, sand, etc., is always expensive. The coarser size stone, passing a $2\frac{1}{2}$-inch ring, with the voids filled by the addition of the smaller sizes, sand, etc., would take 45 cubic feet to make one cubic yard in place, or a yield of 60 per cent.; besides adding to the expense of the handling and being very diffi-



ARRANGEMENT OF FORMS AND TWISTED STEEL RODS, THIRTY-SIX-INCH FLOOR. EASTERN ELEVATOR. TOP VIEW.

cult to properly proportion by the ordinary laborer. Equally good results would be obtained by run of crusher, sand and cement, giving only three ingredients to watch, and resulting in a very material saving in expense. As eternal vigilance is the price of success in concrete work, simplifying of methods is desirable. We err when we introduce refinements, which increase the cost and give no corresponding results.

To produce smooth work, the addition of granolithic face or plastered surface is unnecessary. Smooth forms, with concrete well proportioned, will give just as smooth work at much less cost, leaving the whole mass uniform, without a line of separation or

difference of compressive strength. As an illustration of this, the concrete foundation and floor of the Eastern elevator and the foundations of the new Dakota elevator are good examples, and a cordial invitation is extended to all to examine this work. A large portion of this work was placed in midwinter, proving that good work can be done at all times and seasons, although the expense is about 20 per cent. greater.

Another way to produce finish is to joint the concrete to represent masonry, using rough lumber for forms; then bush-hammering the face, which can be done by an ordinary laborer at 1½ cents per

CONCRETE FOUNDATIONS, DAKOTA ELEVATOR, BUFFALO, N. Y.

All made in February, 1901. Thermometer 0° to 40°. Cost 63 cents per cubic yard to heat.

square foot. The amount saved by using rough lumber goes a long way toward paying for the bush-hammering, which removes all impressions from inequality of molds, efflorescence, etc. The front of the Eastern elevator, facing the dock, is so treated.

The preparation of forms calls for considerable ingenuity, and every contract requires special study, to the end that smooth surfaces be left, with unbroken corners, that the swelling of the wood does not rupture the concrete or leave distorted surfaces; and that the forms be so designed as to be used several times, and readily set up and taken down and later on devoted to other uses. As the

charge for forms against the concrete can seldom be kept below 50 cents per cubic yard for heavy work, there is always an opportunity for the ingenuity of the designer, as few rules can be laid down for his guidance.

The use of matched or tongue-and-grooved stuff is not desirable, as concrete fills in the openings and there is no opportunity to expand from moisture. Unmatched boards dry apart and let the water in the concrete leak out, carrying with it some of the cement. Later on they swell and buckle and, if used as interior forms, burst the concrete. The best way devised so far is to bevel one edge of the boards, using narrow stuff, not to exceed 6 inches. The sharp edge of the bevel, lying against the square edge of the adjoining board, allows the edge to crush when swelling and closes up the joint, preventing buckling.

A coat of soft soap, before filling the forms, prevents the concrete from adhering to the forms, which should always be scraped and brushed with a steel-wire brush when taken down.

Square corners should be avoided, as they readily chip off; and where used as interior forms for recesses or cellular construction, a fillet should always be placed in the corners.

Concrete can often be saved by introducing cells in the mass. These are formed either by cheap hemlock boxes, which can be left in the work, or by collapsible boxes which can be withdrawn and used over again. Where weight is desirable, one-man stone can be rammed in the heart of the mass, reducing the cost very materially.

Where, for economy in handling or other reasons, it is desirable to dump the concrete from a considerable height, some precaution should be taken to avoid having the coarse aggregates separate from the rest of the mass. This can be accomplished in several ways,—either by chains loosely stretched at intervals across a chute or by shelves extending part way across the chute at an incline, so as to deposit on a corresponding shelf on the opposite side, so alternating the length of the chute. Either of these methods is a direct benefit, as it more thoroughly mixes the concrete.

Our building laws as a rule show little knowledge of the value of concrete, ordinarily limiting its use to 16 tons or less per square foot, involving a larger factor of safety than is required for any other material. This probably is due to the large amount of poor concrete turned out, and also to a desire to exclude from the building trades a material that can be placed by unskilled labor.

Regarding the introduction of steel or iron in its various forms in concrete to give tensile strength, there is no question as to its

utility if properly used. I claim no special knowledge of any of the systems except the Ransome, which appears to me the best, for the following reasons: It is a perfect system, from which the entire structure, from foundations to roof, can be made without the introduction of I beams or metal framework of any description, except molding in the cold-twisted square steel bars.

The cold-twisting which the square bars receive has many advantages possessed by no other system. The twisting prevents the rod from drawing in the concrete, making the grip on it continuous and uniform, rendering the strains all equal. It further decreases the ductility of the metal, making it act more nearly in harmony with the concrete,—a vital point when the nature of concrete is considered. Incidentally, we also gain a marked increase in tensile strength, which in practice we generally throw in as an extra factor of safety. The application of concrete-metal is in its infancy, and in a short time I predict it will be used in many ways not now thought of. Its application so far has been markedly successful. The floor of the Eastern elevator is, I believe, the boldest application, to date, of concrete-metal construction. The actual load on the floor is 4470 pounds, and the dead weight of the floor is 300 pounds per square foot, taking the load as uniformly distributed. When we consider that the grain load is concentrated on the rim of the tank, and generally taken as two-thirds of the whole load; that the supporting columns, owing to the peculiar layout of the property, have no relation to the position of the tanks, and that in practice some bins are full and others empty, giving eccentric loading, we see that the problem was a difficult one. The efficiency of the construction is still to be demonstrated. Of its success I have no question. The basement floor of this elevator was built for a live load of 75 pounds, but it has been loaded over almost its entire surface with from 300 to 500 pounds per square foot frequently in seven days after being placed, and that in midwinter.

DISCUSSION.

MR. DIEHL.—Mr. Neher, will you give us a description of the work you are doing at the Eastern Elevator, also at the Dakota Elevator?

MR. NEHER.—The property of the Eastern Elevator is angular, being a rhomboid in plan. The new site occupies the same position as the old elevator destroyed by fire in August, 1900. So far as possible the old piles and masonry piers were utilized. The piers were placed 12 feet centers and at right angles to each other and to the long side of the property. The old plans showed 16 piles

per pier, a heavy timber grillage, and well-proportioned stone piers, stepped up in uniform courses, with equal offsets. Excavation revealed the fact that there were only 12 piles per pier, and that the masonry was laid directly on the pile heads. Many of the piers were of the size of the cap stones, all the way down to the footing stone. In 80 per cent. of these piers the bottom courses of stone were badly broken. As 12 piles per pier were considered insufficient, four more were added in each case, making the load on each pile about 20 tons. Where the old piers were left in, 4 piles were driven outside, and the whole was surrounded with concrete, and prevented from cleaving from the stone by twisted steel bars running around the piers. In the cases where the stone was removed, the 4 piles were added. Excavation was extended 3 inches below the pile heads. One-inch twisted steel bars were laid across the pile heads entirely across the width of the pier in both directions, and concrete was then rammed in the forms until it reached a point 24 inches above the rods. Above this, after thoroughly setting, piers with an area sufficient to withstand a load of 35 tons per square foot were molded, to the height of the basement floor, a height over all of about 7 feet. On these piers, columns 9 feet high and 33 inches square were built, and directly on these was placed the heavy floor 36 inches deep, already mentioned.

The President.—Were the piles driven to the rock?

Mr. Neher.—No, sir. Some few brought up on a hard pan. Most of the piles were driven down from 28 to 35 feet. The hard pan varies at different depths. Some of the piles seemed to be broken in the soil.

Mr. Knighton.—How does this concrete construction compare in price with the ordinary construction?

Mr. Neher.—Taking the price of the materials entering into an ordinary wall, I should say the Ransome construction was somewhat more expensive. While this construction is not a substitute for everything, still I think for work such as we are doing at the Eastern Elevator it is much better than the ordinary construction and cheaper than steel.

Mr. Vander Hoek.—What is the twisted iron put in the concrete for?

Mr. Neher.—To take care of the tension. Where there is to be a great load on a floor I do not think there is anything that will stand like the Ransome system. Before it was taken up by our firm, I studied very thoroughly the matter of the different forms of construction, and I came to the conclusion that this

was the best system for heavy loading. For instance, at Bayonne, N. J., there is a borax factory, the floor of which was built to withstand a pressure of 500 pounds per square foot. There are portions of this floor which have been loaded up to 1200 and 1300 pounds per square foot.

Mr. Vander Hoek.—You spoke of the cement briquettes as breaking at 85 tons after seven days. Were these briquettes of the ordinary form?

Mr. Neher.—They were 6-inch cubes, and we used a hydraulic jack. I think in this case it was Atlas cement. We have used both Atlas and Lehigh, and have got about the same results from each. We sent a boy to the mixer, and he picked out a batch just as it came from the mixer. Where we made tests by hand mixture we did not get as good results.

Mr. Vander Hoek.—You used Portland in every case?

Mr. Neher.—Yes, sir.

Mr. Tutton.—What mixer do you use?

Mr. Neher.—The Ransome. We have made some improvements on it.

Mr. Tutton.—We are using one, but we have not made any tests.

Mr. Neher.—The record made by us is 146 yards in 13 hours, with the small mixer. We laid on an average 41 to 42 batches in 10 hours. This could not be done if fed with wheelbarrows. We fed the machine with a rotating derrick and dump buckets.

Mr. Rockwood.—Did you use any salt?

Mr. Neher.—We always use salt, a 10 per cent. solution.

Mr. Rockwood.—Regardless of the weather?

Mr. Neher.—Yes, sir.

Mr. Vander Hoek.—Did you get the same results in winter as in summer?

Mr. Neher.—We used the same materials in summer as in winter, but I do not think any man can say he got just exactly the same results.

Mr. Rockwood.—Do you use hot or cold water?

Mr. Neher.—We use hot water in winter. We find that with a 10 per cent. solution of salt in hot water, the concrete will not freeze for 5 or 6 hours. This gives us time to fill the forms before covering them up and heating with salamanders.

Mr. Norton.—Did any of the concrete freeze?

Mr. Neher.—Yes, some little did freeze on top. This we capped off.

Mr. Knighton.—What do you consider the best method to follow in leaving off work where you expect to begin next day?

Mr. Neher.—So far as I am concerned, I do not like to leave one day's work uncompleted; but when we do, we generally insert twisted bars placed vertically, to give us union with the succeeding work.

Mr. Knighton.—Have you built any arches?

Mr. Neher.—I have not. Quite a number have been built in the South for railroads.

Mr. Diehl.—I would move you, Mr. President, that a vote of thanks be extended to Mr. Neher for his kindness in addressing us this evening. Seconded by Mr. Tutton. Adopted unanimously by a rising vote.

OBITUARY.

Sherman Emmett Burke.

MEMBER OF THE ENGINEERS' CLUB OF CINCINNATI.

MR. BURKE was born in Cincinnati, Ohio, February 17, 1872, where he attended the public schools in his youth and later was a student of Mt. Auburn Military School and Franklin Preparatory School.

During the spring and summer of 1890 Mr. Burke was employed on the location and construction of the Middletown and Cincinnati Railroad, of which his father, Major M. D. Burke, was chief engineer. In the latter part of the year Mr. Burke entered the preparatory department of the Ohio State University, and matriculated with the class of 1895 in the course of civil engineering.

In his college career Mr. Burke was a charter member of Beta Nu Chapter of Sigma Nu Fraternity, and captain of Company D of the university battalion, where he distinguished himself by winning the prize sword in 1894.

In June, 1894, Mr. Burke accepted a situation in the engineering department of the Cincinnati, Portsmouth and Virginia Railroad, under the direction of Mr. W. B. Ruggles, chief engineer, where he remained until March, 1895, when he entered the service of the Cincinnati, Lebanon and Northern Railway Company as engineer.

In June, 1895, Mr. Burke entered the service of the Pennsylvania Company, and was assigned to the Newport and Cincinnati bridge corps, under the direction of Mr. George U. Engle. Mr. Burke remained with the Newport and Cincinnati bridge corps until the completion of the substructure, after which he accompanied Mr. Engle to Indiana, where they were engaged in survey work, and later became part of the chief engineer's office force at Pittsburg.

The energy and fidelity displayed by Mr. Burke soon attracted the attention of the officers of the Pennsylvania Company, who evinced their appreciation by making him assistant engineer of maintenance of way of the Richmond division of the Pennsylvania lines July 1, 1897.

On July 1, 1899, Mr. Burke was transferred to the Cleveland, Akron and Columbus Railway, of which he was made engineer of maintenance of way November 1, 1899, remaining in that capacity until his death.

On October 17, 1900, while accompanying the general manager's inspection party, Mr. Burke received accidental injuries

which resulted in his death. Mr. Burke leaves a widow and daughter to mourn their loss, and a host of friends who regret with deep feeling that a promising and useful career was cut short by his untimely death.

J. A. Rabbe,
J. A Lilly.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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THE SOFTENING OF FEED WATER FOR BOILERS.

BY LOUIS BENDIT, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, April 3, 1901.*]

IT certainly is unnecessary in this advancing scientific age, and before this society, to prove the facts that nearly all waters that are found either in streams or beneath the surface of the earth are impure or that water purification is essential, whether for dietetic or manufacturing purposes. This is conceded by every engineer.

In this paper we shall consider only the best method for the treatment of feed water for boilers.

All natural water contains two classes of impurities, viz., organic and inorganic, either in suspension or in solution. The organic impurities are of vegetable and animal origin, and are taken up either in flowing over the ground or by direct contamination, such as the addition of sewage from cities or refuse from manufacturing concerns. This evening we shall consider only the soluble inorganic or mineral impurities, for it is these which give trouble and cause expense when the water is used in steam boilers.

The mineral impurities in solution are the lime, magnesia, soda and potash in combination with carbonic, sulphuric or hydrochloric acids, with iron, generally as a bicarbonate, and a small amount of silica.

The soluble lime and magnesia are the impurities which make water hard. The hardness of water is measured in degrees, as parts per thousand, or in grains per gallon. All salts of lime and

*Manuscript received May 27, 1901.—Secretary, Ass'n of Eng. Socs.

magnesia are figured to their chemical equivalent of lime carbonate, and each part per 100,000 is called a degree of hardness. Thus, we say a water has a hardness of 10 or 50, as the case may be, meaning that when all lime and magnesia salts are figured to the lime carbonate, the water contains 10 or 50 parts per 100,000. The hardness of water may be measured in a very simple manner by means of a standard solution of soap in alcohol, the strength of the solution being tested by means of a solution of calcium chloride of known strength. Soap will not lather or form suds with water until all the lime and magnesia are precipitated, for the principal action of soap is that of softening water, and, in making the test, we take advantage of this fact by adding the standard soap solution to known volume of water, until a permanent lather is formed.

A part of the carbonates of lime and magnesia may be removed from water by boiling, also a portion of the lime sulphate, if it is present in considerable amount. The number of degrees of hardness removed by boiling is called temporary hardness; that remaining, permanent hardness. From this it will be readily seen why exhaust steam heaters fail to complete the work, for, at best, they can remove only the temporary hardness, leaving chlorides, nitrates and the greater proportion of the sulphates to pass on into the boiler, where scaling and corrosion take place. Of course it is impossible to use an exhaust steam heater to purify water in condensing plants. When hard water is used in steam boilers, the heat drives off the carbonic acid, precipitating the carbonates of lime and magnesia. This takes place at 212° F. for an interval of two or three hours.

Furthermore, the continual evaporation of water in a boiler concentrates the impurities, until finally a point of saturation is reached. This, combined with the heat of the high-pressure steam, causes a precipitation of the sulphates of lime and magnesia together with some of the more soluble impurities.

These are called the scale-forming impurities, because a crust or scale forms or accumulates wherever the hot water comes in contact with the metal. This scale is built up of thin layers of precipitated lime, magnesia, silica and iron. On the inside of the boilers it covers the tubes and plates, generally being thickest where the circulation of the water is least.

The consequences are generally serious, because the scale is a non-conductor of heat; carbonates of magnesia having a relative value of from 0.67 to 0.76 as non-conducting materials (felt or wood being taken as 1). It is claimed that the conducting power of iron is about thirty times that of saturated scales.

While it is true that the well-known "Tables of Loss of Fuel Due to Scale," printed and circulated by manufacturers of scale preventatives, are very much exaggerated and probably entirely incorrect, still it has been proved by practical experiments that a metal is heated to much higher temperature in boiling water if it is covered with a non-conducting material than if the metal is clean.

If a boiler is heavily incrusted with lime, there is great danger of overheating the metal, because the water is not in immediate contact with the steel and cannot carry off or absorb the heat from the plates. The boiler, being under pressure, the overheating of the metal results in a stretching of the plate, forming a "bag," or the metal may blister and crystallize, and this will very much reduce its tensile strength, rendering the boiler unsafe.

This means that repairs are necessary. Even in cases where the metal does not get hot enough to bag or blister, it expands unequally, destroying the seams and joints between the several parts of the boiler, thus causing leaks, which in time become serious enough to put the boiler out of use.

Even where no disastrous results follow, much labor upon the part of the engineer in charge is necessary to keep the scale from accumulating. The scale is usually very hard, and can be removed only after considerable hard work. The continual hammering and chipping necessary for this is injurious to the metal, and, even if the cleaner's intentions are the best, it is impossible to reach and clean all parts of the return tubular boiler.

HEATERS AND MECHANICAL PURIFIERS.

The boilers are not the only part of the steam-generating plant affected by the impurities of the water. A deposit of a part of the carbonates of lime, magnesia and iron takes place as soon as the temperature begins to rise, which is when the water reaches the exhaust steam heaters. The first heaters built consisted of a coil or a number of pipes enclosed in a metal housing. The water was pumped through the inside of the pipe, and the exhaust steam in the chambers surrounding it heated the water. Used in places where the water contained only a small amount of lime and magnesia carbonates, no trouble was experienced; but when this type of heaters was tried to heat waters containing a large amount of lime carbonates, as do our western waters, these heaters were rendered useless in a very short time. The water passages through the pipe became clogged, and no water could be forced into the boiler.

Because of the fact that the carbonates are partially precipi-

tated by the heat of the exhaust steam, heater manufacturers have called their exhaust steam heaters "purifiers," and have so modified them that they can be readily cleaned.

The same trouble arises in plants using economizers, or heaters through which the water passes after it leaves the exhaust steam heaters and before it reaches the boilers. These get their heat from the waste gases of the furnaces, and it is very important that their surfaces be cleaned and kept so, without involving great labor and expense.

The exhaust steam heater, as purifier," has helped the trouble only in part, because the sulphates, which form the hardest scale, are not precipitated at all at the comparatively low temperature of the water from an exhaust steam heater; for that reason they pass on to the boiler and collect on its surfaces. To remedy this, a second tank, like a boiler, filled full of pans or shelves and heated with live steam from the boiler, is tried.

Into this receptacle all the water passes before it finally reaches the boiler. By carrying this heater at boiler pressure, the water becomes hot enough to start the precipitation of its sulphates. This is not an instantaneous process, but a gradual one, and it continues after the water has reached the boiler. Of course the efficiency, in all mechanical purifiers depending upon heat, is proportional to the length of time during which water is subjected to the heating or purifying process. In practice the water is never thoroughly purified in exhaust or live steam purifiers, because the heater is usually so small that the water passes through it in too short a time to complete the precipitating process.

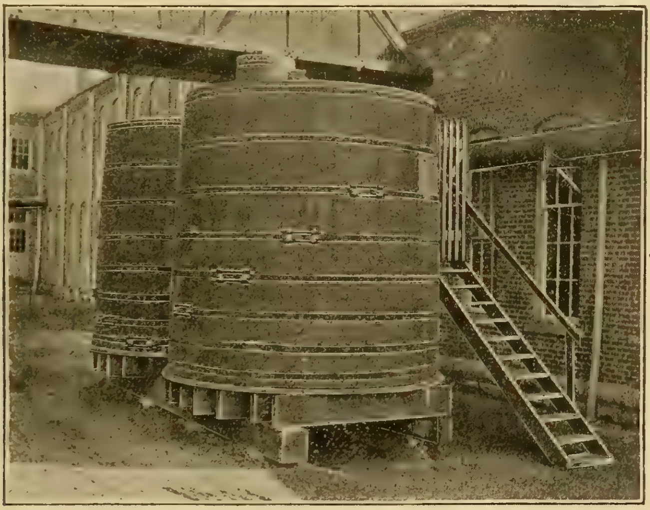
Sulphate of lime is said to be completely insoluble at temperatures above 300°. This is true, provided there is a certain amount of it in the water.

Analyses of water from the blow-off valves of boilers show that the sulphate of lime in solution is as high as 25 grains per gallon, even when the temperature is far above 300°. From this it is evident that it is due to the concentration as well as the heat that the sulphate of lime precipitates in the boilers, forming scale. Concentration does not take place either in exhaust or in live steam heaters.

The introduction of soda ash into the feed water in an open heater has been tried, and, where the character of the water is not bad, this method has helped somewhat; but where the water contains the average amount of impurities, it is of little or no advantage, and, as far as we can discern, the soda ash might just as well be fed to the boiler direct, for the average heater is so small that it is impossible fôr the precipitation to be completed then.

To show that this is true, we will take water of an average condition, say 14 grains of carbonate of lime to the gallon, and 1000 horse power boiler plant evaporating 100,000 gallons of water in twenty-four hours for a six-days' run. That means about 7,500,000 grains or 1000 pounds, or 5 barrels, of carbonate of lime. Of course, no 1000 horse power heater ever had that quantity of residue in it at one time, because it cannot get all the lime of the water in that way; and, were the heater allowed to run long enough to accumulate that amount, it would become clogged so that the water could find no egress to the feed pump.

Except in the case of waters low in scale-forming matter, this method is attended with many objections.



WATER-SOFTENING AND PURIFYING PLANT, CLARK'S PROCESS.

At the Crawford, McGregor & Canby Company's Works, Dayton, O.

First. There is the mechanical problem of disposing of the voluminous precipitate which hard waters give up when they are properly treated.

Note the above that even 14 grains of carbonates per gallon mean 1000 pounds at the end of a week's run of a 1000 horse power plant, and this does not include the sulphates or chloride precipitated by the soda ash.

Second. The heater, of course, can be cleaned advantageously only when the plant is shut down. Carbonates precipitated by heat cannot be blown from a pipe, as can those precipitated by a chemical treatment.

Third. The purifiers operate upon the continuous process plan, feeding a soda-ash solution into the raw water; the result is that the feed pump fills with precipitated lime, and this either decreases the supply or shuts it off completely. If larger feed pipes are used, too much ash goes to the boiler, and the water foams. The average engineer has too much to do to nurse the feeds, so that they are out of order about half the time, and no better results are obtained than with a plain exhaust heater.

In the above-mentioned 1000 horse power installation, with the use of a water-softening plant of the intermittent type, the cost of precipitating the carbonate of lime would be less than $2.50 per week, which certainly is much less than the expense of removing 1000 pounds of lime from an open heater, to say nothing of the important fact that the open heater would fail to accomplish the desideratum, whereas the water-softening plant would accomplish it.

Innumerable other mechanical devices have been tried to overcome this trouble, such as skimmers, surface blow-off, etc. Notwithstanding all these efforts, scale continued to form on the plates and the tubes of boilers. There seemed to be another way, and that was to supply to the hot water in the boiler itself a remedy which would keep the scale from hardening.

BOILER COMPOUNDS.

Mixtures known as "boiler compounds" have been used for years. These are generally composed of soda in combination with some organic acid, such as tannic acid, acetic acid, etc. All of these acids are said to corrode the metal and to be positively injurious to the boiler. Almost everything has, at one time or another, been put into a boiler to keep the scale soft, such as oak bark and shavings, because of the tannic acid they contain; distillery slops, on account of their acetic acid; potatoes, corn, etc., for their starch, leather, slippery elm and manure, for the gelatinous matter; molasses and sugar, because of the saccharates of lime formed. Innumerable other substances have been used without judgment or reason.

Prof. Robt. H. Thurston, in his "Manual of Steam Boilers," page 463, says that logwood, hemlock and other woods are sometime employed, but are apt to injure the iron of the boilers, as may acetic or other acids contained in the various saccharine matters, which also make the lime sulphate scale more troublesome than when clean. Organic matter should never be used.

From a chemical standpoint the most efficient boiler compounds are trisodium phosphate and fluoride of sodium. With these, when the water is heated, both carbonates and sulphates of

lime and magnesia are precipitated as phosphates or fluorides, which do not harden upon the tubes and shell. The principal objection to them is the cost of using them in quantities sufficient to remove enough of the scale-forming matter to be of benefit. There are two reasons why they are expensive. The chemical equivalent of these compounds makes it necessary to use one pound of trisodium phosphate to precipitate either 0.9 pound of carbonate of lime, or 0.77 pound of carbonate of magnesia. One pound of fluoride of sodium is required to precipitate 1.19 pounds of lime carbonates or 1.6 pounds of lime sulphates; and its cost, at present writing (1901), is about two and one-half times as much as that of the trisodium phosphate.

One pound of caustic lime will precipitate 1.78 pounds of lime carbonate, or nearly twice as much as will trisodium phosphate, while its cost per pound is about one-eighteenth as much, or it will remove one and one-half times as much carbonate of lime as will fluoride of sodium, which costs about forty times as much per pound.

Therefore, with the same expenditure of money, caustic lime will precipitate about thirty-six times as much carbonate of lime as will trisodium phosphate, and about sixty times as much as will fluoride of sodium.

Because of the cost, the amount of either trisodium phosphate or fluoride of sodium put in boilers is but a small percentage of the true amount necessary for complete precipitation of the scale-forming matter. That part which is converted into a phosphate or fluoride of lime or magnesia, mixes with the heat-precipitated carbonates, and mechanically prevents them from getting very hard, although they do not or cannot prevent the remainder of the lime carbonates from precipitating by heat.

Another reason why the large amount of these compounds necessary for complete precipitation cannot be used is because too frequent blowing off is required in order to prevent the water in the boilers from becoming saturated with soda by the continual concentration of the impurities and the continual addition of the compound.

The vegetable boiler compounds consist of sugar and tannins mixed with slippery elm or powdered wood pulp to furnish a soluble starchy substance. The tannins convert the carbonates into saccharates, which are blown out. One pound of tannic acid is required to precipitate one-seventh of a pound of carbonate of lime, and one pound of saccharic acid will precipitate about five-eighth of a pound of sulphate of lime.

Comparing these chemical compounds with a proper water-softening treatment, it is readily seen what a large amount of wholly unnecessary foreign matter must be put into a boiler in order to form a small amount of lime sludge which will not harden on the tubes and plates, even if no other objections arose.

It should be clear to anyone why boiler compounds fail to keep a boiler free from scale except in waters containing a very small amount of incrustating solids, such as some surface waters from rivers, lakes, ponds, etc.

Kerosene oil, which is used extensively, is entirely mechanical in its operation. It does not convert any of the scale-forming material into a non-hardening condition, because there is no chemical change; but owing to its light, volatile nature, it penetrates a porous scale and tends to disintegrate it. When the boiler is cold, the rotten scale partially breaks off from the metal, and is removed when the boiler is opened. It is the appearance of the rotten scale which makes it seem as if the boiler must be clean, whereas actually they are quite dirty, for but a small portion of the total amount has been removed. The volatile nature of this material prevents its use in any place where a pure steam is required, and it should never be used where a steam-heating apparatus is employed, because the volatile hydrocarbon distilled causes leaks at joints, fittings and valves.

WATER SOFTENING.

The process known as water softening, based upon the exact quantity and chemical character of the impurities, offers the relief desired. It is a method based upon accurate chemical knowledge, and it does not depend upon the change or imagination of any man to prove its efficiency. A chemical process involves an expense due to the reagents used; therefore, in order to keep down the cost to a minimum, only the cheapest and most efficient reagents can be employed.

The Clark process of precipitating carbonates of lime and magnesia by means of caustic lime is undoubtedly the cheapest chemical method; that, combined with soda-ash treatment for the sulphates and chlorides, makes it possible to get a clear feed water low enough in scale-forming to fulfill all requirements.

True water softening is an exact process. By this is meant that the exact amount of caustic lime must be put into the water to remove all the carbonates of lime and magnesia present; and the exact amount of soda ash used to decompose all the sulphate of lime and chloride of magnesia. No more, no less.

If it is desired to run at the lowest possible cost for operation, the method of treating the water and the apparatus used must be so simple that a man can operate it who has no knowledge of chemistry, and of whom nothing but mechanical work is required.

The apparatus which has been designed to accomplish this may be divided into two classes, viz., the intermittent and the continuous.

The apparatus designed for the continuous process consists usually of a steel settling tank, in which the water, after the addition of lime and soda water, is made to flow through spaces between series of intercepting plates in order to effect a mixture of the reagents with the water, which then passes to the bottom of the tank through a pipe, and thence rises again nearly to the top, where it overflows in a continuous stream.

Exact and uniform treatment is difficult to obtain, especially in our turbid western waters.

First. Because the amount of caustic lime or of soda ash dissolved in a gallon of solution may vary.

Second. Because the change of pressure may vary the amount of raw water supply, changing the whole character of the effluent.

Third. Because it is a difficult matter to keep uniform the amount of the chemical solution flowing through the small orifice into the raw water.

Fourth. The interior pipes or openings are likely to become incrusted, causing a variation which effects the results.

Fifth. Because no machine yet built will regulate the amount of lime and soda in the same proportion as the amount of raw water flowing through the machine, when the demands are irregular. At certain hours of the day (during the peak of the load) the demand for feed water is often triple that of other times.

The intermittent system consists of two or more settling tanks, provided with agitators in order to thoroughly mix the lime and soda with the water in one tank, after which the water is allowed to settle while the water in the other is being treated or being drawn from it. For drawing off the clear water, use is made of a pipe on a movable joint near the bottom of the tank, its other end being supported near the surface by a float. By this means clear water may be drawn by the time the precipitate has settled a few feet. In this machine water can be softened with great accuracy and uniformity.

This plan is the original one, and for certain demands is the cheapest. The principal objection to it is the ground room it occupies. The necessity for using very large tanks has been overcome by using a filter to mechanically remove the floating lime sludge, which does not completely settle in the time allowed in small

tanks. This plan is in no sense an obsolete one, for plants are being installed at the present time in England and in this country among the largest manufacturing concerns, and for use in city water works.

To some the settling-tank plant may seem crude in comparison with the more elaborate plants working upon the continuous process. The expensive continuous water-softening plants are not necessary for good softening, and generally they are more difficult for the average man to operate satisfactorily.

On account of the expense of installing the plant, the continuous process is the only method which can be used where very large quantities of water are to be softened; that is, in plants furnishing two million gallons a day or more. In order to get satisfactory results from a continuous process water-softening plant, it should be in charge of a man who is expert in handling such apparatus, or where the services of a chemist are constantly available.

Among the many advantages of the intermittent settling-tank plant are:

First. The absence of automatic chemical feeds.

Second. It can be operated by the engineer or his assistant, without interfering with their regular work.

Third. A constant quantity of raw water is collected, to be treated with a uniform amount of chemical reagents. By this plan an excess or insufficiency of chemicals is avoided, and, therefore, a uniform character of softened water is furnished, while the simplicity of the apparatus enables an unskilled workman to obtain as good results as an expert chemist.

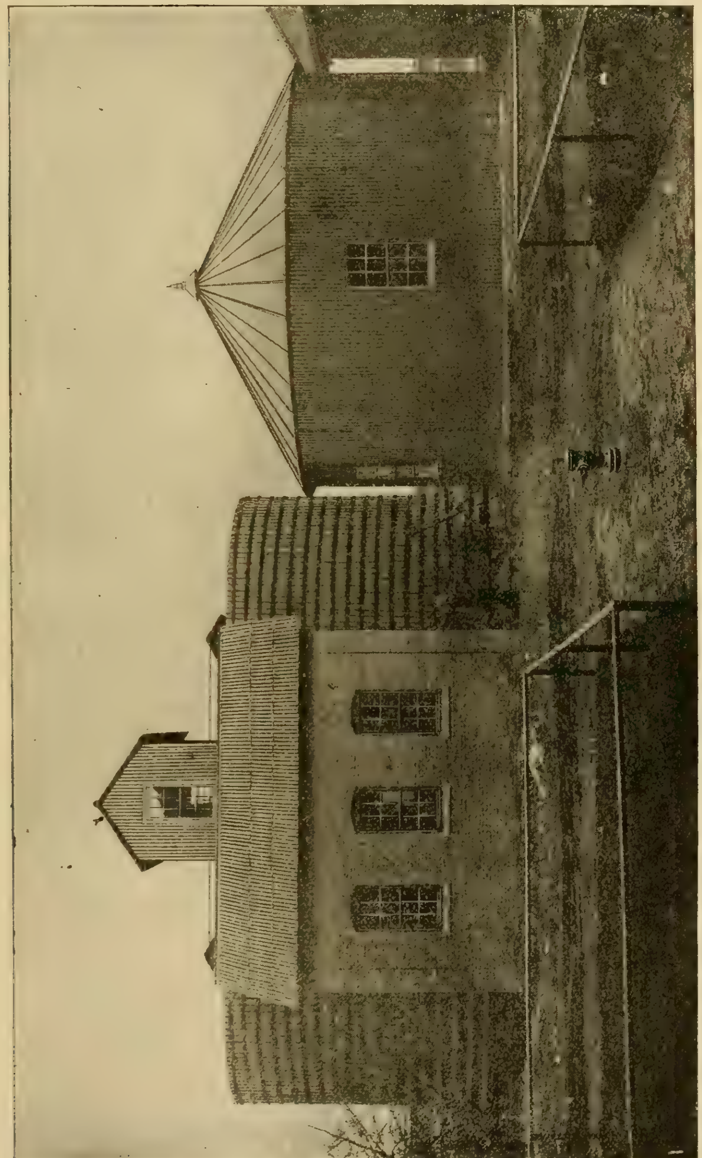
Fourth. The mechanical stirring, resulting in an agitation of raw water with the chemicals, insures an intimate mixture, and very materially hastens and soon completes the chemical reaction.

Fifth. The sludge of previous purification, which has settled to the bottom of the tanks, is mixed with the water by the action of the mechanical stirring device. This insoluble matter, moving in the water, gathers together the new, finely divided precipitate of lime and magnesia. This aids the chemical reaction, and hastens the settling and clarifying of the water.

Sixth. The sludge, collected in the settling tanks, relieves the filter beds, so a filter can be run five or six times as long without cleaning as would be the case were all sludge intercepted by the filters.

Seventh. Inasmuch as these settling tanks do not usually require washing or emptying oftener than once a week, the account of waste water, required for cleaning or removing of sludge, is a very small percentage of the total amount purified.

Eighth. The water must stand for some time in order to get a complete chemical reaction between the soluble impurities of the water and the chemicals added to it. Every chemist understands



WATER-SOFTENING PLANT, TONAWANDA IRON AND STEEL CO., NORTH TONAWANDA, N. Y.

that no chemical reaction is instantaneous. If the lime and magnesia are not completely removed in the purifying apparatus, they are sure to precipitate in the pipes, heaters and boilers.

Ninth. The perfect quiet of the water gives an opportunity for complete settling, and renders the unfiltered water clearer than that from any other apparatus not using filters, or that from exhaust steam heaters in which crude filters are placed.

Tenth. The operation of this apparatus is the method followed by a chemist in a laboratory, but on a larger scale and with minor modifications to suit conditions.

Eleventh. This arrangement of two settling tanks permits an accurate daily record to be kept of the amount of the water evaporated in the boilers. This feature will be appreciated by careful and economical managers of large steam plants who are watching their coal piles.

The tanks are made of wood, brick or steel plates, and are generally cylindrical. The size of these reservoirs depends upon the quantity of water required per 24 hours, and the condition under which they are operated.

For plants requiring up to 4000 gallons per hour, we advocate two tanks, each having a capacity equal to six hours' supply. In plants with 8000 gallons per hour, we use two tanks, each having four hours' supply, and in all sizes above 8000 gallons hourly capacity, we use two tanks, each having a two hours' supply.

The two-hour tanks require more frequent attention, but these may be placed in charge of a boy, who can operate them, under the supervision of the chief engineer, with as good results as a man.

They are filled alternately with hard water. The chemical reagents are mixed in a small tank placed upon the top of the settling tanks, and are washed into the water while the tank is filling. A mechanical stirring device, consisting of a paddle revolved by suitable gearing, and operated by hand or liquid power, depending upon the size, mixes the hard water and the reagents together, at the same time stirring up from the bottom the lime sludge of the previous purification. This floats in the water, hastening the chemical reaction, and causes the new, finely divided carbonate of lime precipitate to gather into large flocculent or woolly flakes, heavy enough to settle quickly as soon as the water stops moving.

This paddle-stirring device is the simplest and the cheapest in the market. With reasonable care it cannot get out of order; it does not have to be cleaned to keep it in working condition, and does not require a large quantity of high-pressure steam to operate it. It should be run by a belt, carried from a shaft in the building, or by a small, independent steam engine or electric motor.

The power required varies from 1 to 3 horse power, so that the amount of steam consumed for this power is extremely small. By

exhausting the steam from the stirring engine into the coil pipe in the settling tank, the water becomes slightly heated. In cold weather this prevents it from freezing, and at all times hastens the chemical reaction.

The softened water is taken out of the tank by means of a hinged, floating outlet pipe, arranged to rise and fall with the level of the water, so that the clearest water is drawn from the top of the tank. By this arrangement a deep tank has all the advantage of a shallow one as a settling basin, because the water from the top carries the least amount of floating lime sludge into the filter beds, and in that way the filters can run the longest possible time without being cleaned, the time varying from three to seven days.

Inlet connections, through which to fill the tanks and wash the pipe connections, and to wash lime sludge from tanks, are placed in the bottom.

The washing of the settling tanks needs only to be done when the lime sludge becomes deep enough to interfere with the settling. The lime, once precipitated, does not redissolve in water. These tanks are cleaned once in four to six days, depending upon the amount of sludge collected. All that is necessary is to open the wash valve and start the stirring device to mix up the lime sludge, which is soft enough to run readily through pipe.

In small plants the sheet-iron chemical tank is placed on top of the settling reservoirs; in large tanks, at the bottom. In the latter case, a small centrifugal pump is used to pump the chemical solution into the tanks.

By using this simple plan, the chemicals are partially mixed with the hard water. The mixture is completed by the revolving paddles of the stirring device, which is started as soon as the filling of the tanks begins, and runs until the tank is full.

When pressure filters are used, the settling tanks are placed about three feet above the ground, but when open or gravity filters are used, the tanks are elevated about eight feet above the ground, or the filters must be lowered to allow water to flow into them from the settling tanks by gravity.

The instructions given for operating these plants are extremely simple, so that any man of average intelligence has no difficulty in understanding and using them.

When an old boiler is first fed with softened water, it must be opened every week until the old heavy scale is removed, otherwise there is great danger of the loose scale collecting on the fire sheets and burning the iron or causing a bag.

The water does not foam, provided the blow-off cock is used regularly, thus preventing a concentration of those impurities which cannot be removed by any purifying process or apparatus. The water has a less tendency to pit or corrode the metal than hard water, and a very small amount of combined carbonic acid. Its mineral acids, hydrochloric and sulphuric, are combined with soda, for which they have a strong affinity. The water is either slightly alkaline or neutral, but never acid.

This apparatus will render the most turbid waters clear, because the large amount of sediment found in some waters, which is so difficult to filter by a continuous-process plant, is, in this apparatus, the means by which the water is cleared. That is, the mud or sludge of previous purification helps to remove that of the new raw water, and at the same time it does not deposit on the filter beds, and thus necessitate frequent washing.

TESTING THE WATER.

Careful chemical analyses have shown that all waters vary in the amount of mineral impurities at different seasons of the year. This is especially true of surface waters from rivers, lakes, etc., but even upon waters from deep wells, the amount of rainfall has a marked influence.

For this reason, and also because the tanks may be filled to different levels, it is necessary to test the water in order to determine whether the correct amount of caustic lime is added to the hard water. To do this, two chemical solutions are used: one to show when not enough caustic lime has been added; one to show when an excess has been used.

We have proved by experience that there is no difficulty at all in the successful use of these test solutions on the part of any careful and reasonably intelligent man. The change of water is not a daily one, but rather one that takes place from week to week, and, by testing the water once every day or two, it can be kept uniformly satisfactory.

There is no satisfactory test that can be employed outside of a laboratory to determine the correct amount of soda ash, but a slight excess of soda ash is not objectionable, but rather beneficial for water used in steam boilers. Hence, when the water is used for that purpose, it is not necessary to test the water for this soda ash. All that is then required is to use enough.

Should any scale form in the boilers, its appearance and character will indicate, to an observant man, whether it is the sulphate or the carbonate of lime, and from this he should know whether it

is necessary to increase the amount of soda ash, and whether he is using enough of lime.

Equally important, with the selection of an efficient boiler, is the character of the feed water, and its treatment, so as to maintain the original efficiency that modern boilers give when in prime condition. Therefore, when a new boiler plant is installed, and when more than one source of water is available, it will certainly pay, in a majority of cases, to investigate each water, and so determine which is best for boiler use, and which will most readily yield to treatment and thus prove the cheapest.

In the city of St. Louis, where not less than ten cents is paid for each 1000 gallons of water used, and in other cities where a 50 per cent. greater tax is collected, it will, in many cases, pay to sink wells and treat the water thus obtained, which will seldom cost, for treatment and pumping, one-quarter of the price of city water.

COST OF SOFTENING WATER.

All carbonates of lime and magnesia, and iron are removed by caustic lime, which is also precipitated and removed along with the original impurities. By means of soda ash, sulphates of lime and magnesia, or chlorides of lime and magnesia are converted into carbonates of lime and magnesia, and hydrate of magnesia, which are precipitated, while the soda unites with the sulphuric and hydrochloric acids, forming the neutral sulphate of soda and chloride of sodium, which are soluble in water.

The caustic lime used must be as pure a calcium oxide as it is possible to obtain. A "fat" lime is generally of this character. A high percentage of magnesia, oxide of iron or silica, is objectionable.

The cost of treatment of water varies from one-third cents per 1000 gallons up, depending upon the character of the water.

The advantages of this method of feed-water purification are self-evident.

First. The water is softened while cold, and before it enters the boiler room; therefore, the feed pipes, exhaust and steam heaters and economizers are kept practically free from calcareous deposit.

Second. The softened water contains a very small amount of incrustating matter. Therefore the boiler can be operated many times as long without cleaning and does not collect a hard scale.

Third. When it is necessary to wash out a boiler it can be done for about one-third of what it cost before the water-softening plant was put in.

Fourth. The purifying apparatus can be cleaned advantageously while the steam plant is in operation, thus saving Sunday work or overtime.

TABLE SHOWING AMOUNT OF IMPURITIES REMOVED FROM WATER BY CHEMICALS USED IN SOFTENING.

One Pound of the Following Chemical	Will Remove Following Amount in Pounds: At Price in Cents per Pound.	Carbonate of Lime.	Carbonate of Magnesia.	Sulphate of Lime.	Sulphate of Magnesia.	Chloride of Lime.	Chloride of Magnesium.
Caustic lime, 98%	¼–⅓	1.75	1.5	....	....	....	....
Soda ash, 58%.....	.88–1.15	....	....	1.28	1.13	1.04	0.9

Fifth. The scale-forming matter in the water is reduced to that condition in which it can be gotten rid of, at the least possible expense; a small fraction of the cost of cleaning heaters or boilers.

Sixth. No boiler compound is required.

Seventh. An increased economy resulting from clean boilers.

Eighth. Less water used for cleaning, and less coal used for heating up the cold boiler and brickwork, due to less frequent cleanings.

TABLE OF COST OF PRECIPITATING 1000 GRAINS OF DIFFERENT IMPURITIES WITH DIFFERENT REAGENTS.

Reagent.	Cost of Reagent per Pound.	Carbonate of Lime.	Carbonate of Magnesia.	Sulphate of Lime.	Chloride of Magnesia.
Caustic lime, 98% pure........	3–10c.	.0255c.	.0296c.	....	....
Soda ash, 58%....................	1–½c.	....	....	.167c.	0.243c.
Caustic soda, 74%..............	3c.	.3570c.	.4070c.	....	....
Trisodium phosphate............	5c.	.7850c.	.928c.	.576c.	0.831c.
Fluoride of sodium..............	10c.	1.2000c.	1.430c.	.883c.	1.26c.
Tannic acid........................	5c.	4.5750c.	5.475c.	....	....

Ninth. The saving in repairs.

Tenth. The increased safety to life and property by decreasing the danger of explosion, either of boilers or of high-pressure heaters.

Water from which the incrustating solids and mud are removed before it reaches the boilers or heaters, so that not over 1 grain of lime carbonate and $1\frac{1}{2}$ grain of magnesia hydrate are found in a gallon of water, is in such a degree of softness, that not more than a "paper" scale will accumulate on the plates and tubes of steam boilers in six months of constant use, and but a small amount of soft deposit upon the pans of the exhaust steam heaters.

This is the condition to which a hard water can be brought by means of the Clark process. The figures show a plant on this system, erected in the works of the Crawford, McGregor & Canby Co., at Dayton, Ohio.

The following are analyses of well water, before and after softening in this apparatus:

ANALYSES OF WATER, BEFORE AND AFTER SOFTENING BY THE CLARK PROCESS, AT THE LOUISVILLE ELECTRIC LIGHT CO., LOUISVILLE, KY.

IMPURITIES GIVEN IN GRAINS PER U. S. GALLON.

	Raw Water.	Softened Water.
Silica	1.10	.40
Oxide of iron and aluminum	.30	.10
Carbonate of lime	16.78	.80
Carbonate of magnesia	1.89	....
Hydrate of magnesia	....	1.04
Sulphate of magnesia	....	9.90
Chloride of sodium	8.40	6.09
Sulphate of soda	6.00	....
Total	34.56	18.33

Take, for example, Michigan Lake water, the cost of softening which is 0.34 cents per 1000 gallons.

For a 100 horse power boiler, operating 12 hours and evaporating 4050 gallons, the cost of softening is 1.4 cents per day; cost per year (350 days), $4.90.

With Lake Erie water the cost of softening is 0.80 cents per 1000 gallons; cost per day per horse power, 3.25 cents; cost per year, $11.38.

DEEP WELL WATER FROM SOUTHERN OHIO.

IMPURITIES GIVEN IN GRAINS PER U. S. GALLON.

	Before Softening.	After Softening.
Oxide of iron	.630	....
Carbonate of lime	10.768	1.450
Carbonate of magnesia	4.777	....
Hydrate of magnesia	....	.870
Sulphate of lime	1.725	....
Sulphate of soda	....	1.802
Chloride of sodium	2.080	2.080
Total residue	19.981 grains.	6.172 grains.
Hardness (Clark)	17.5 degrees.	3.0 degrees.
Theoretical soap-destroying power, per 1000 gallons of water	26.000 pounds.	4.500 pounds.

Cost of chemicals to remove temporary and permanent hardness, $5.02 per million gallons.

Cost of chemicals to remove hardness only, $4.35 per million gallons.

Where formerly it was necessary to open boilers for cleaning once in ten days or two weeks, and then the cleaning consisted in scraping, hammering and chipping the scale from the tubes, by the

use of softened feed water, a boiler will run from twice to four times as long, and nothing but a stream of water from a hose is necessary to clean the soft white sludge from the metal; this requires but a fraction of the time used for cleaning by the old method.

An exhaust steam heater will run about twenty-four times as long before it has an equal deposit on the pans. Where economizers are used, the softened water keeps these clean for the same reason.

When used in boilers heavily scaled, this softened water has a tendency to remove the old crusts, because no new deposit of lime and magnesia forms over the old crusts, thus cementing it to the metal while the boiler is hot. The unequal expansion of the metal and of the non-conducting crust loosens the latter, and it falls from the tubes and plates. The action is practically the same as that noticed when rain water or distilled water is used in boilers.

ECONOMY IN OPERATION OF 2000 H. P. STEAM PLANT, DUE TO USING WATER-SOFTENING PLANT.

Cost of Operation without Water-Softening Plant.

Cleaning five 400 H. P. boilers, each once in 2 weeks, 130 cleanings per year, at $20	$2,600.00	
130 tons of coal, at $1.30 per ton, to get steam on boilers cooled by cleaning	195.00	
Yearly extra repairs on five boilers, due to bad water	150.00	
Boiler compound for five boilers, per year	300.00	
		$3,245.00

Cost of Operating with Water-Softening Plant.

Yearly cost of chemical reagents to treat 60,000 pounds of water per hour, at ⅞ cent per 1000 gallons	$551.88	
Yearly interest 8 per cent., and depreciation 10 per cent., on $4500	720.00	
Yearly labor of operating plant, at 90 cents per day	328.50	
Washing five 400 H. P. boilers, each once per month, or 60 washings per year, at $8	480.00	
60 tons of coal at $1.50 per ton, to get steam on boilers cooled by washing	90.00	
		2,170.38
Saving by using softened water (about 24 per cent. on $4500)		$1,074.62

Coal Economy.

2000 H. P. boilers evaporate 60,000 pounds of water per hour, or 1,440,000 gallons of water per 24 hours. Evaporation without purifier at 10 to 1 equals 144,000 gallons; 72 tons of coal per 24 hours, at $1.50 per ton, = $108 per day, or, per year	$39,420.00	
If evaporation were increased to 10.10 pounds of water per pound of coal, due to having boilers free from scale, 1,440,000 pounds of water should be evaporated each 24 hours with 71.28 tons of coal, at $1.50 per ton, a yearly cost of	39,025.8c	
		394.20
Estimated saving about 32.6 per cent. on $4500 investment		$1,468.82

TABLE SHOWING CHARACTER OF WATERS FROM DIFFERENT LOCATIONS, AND CONSEQUENT DIFFERENCE IN COST OF SOFTENING.

	Source.										
	Lake Michigan, Chicago.	Lake Erie, Lorraine, Ohio.	Deep Well, Dayton, Ohio.	Deep Well, Indianapolis, Ind.	Deep Well, Louisville, Ky.	Well, Harvey, Ill.	Rio Grande River, El Paso, Tex.	Well, Cincinnati, Ohio.	Lima, Ohio.	Decatur, Ind.	Desloge, Mo., Mine Water.
	Impurities in Grains per U. S. Gallon.										
Organic matter	1.875	.830	....	....	....	....	.830	....	....	....	....
Silica	....	....	....	....	1.10	....	.830	.830	.60	.960	.80
Oxide of iron and aluminum	....	....	....	....	.30	.830	.630	1.455	....	1.960	.20
Carbonate of lime	4.764	4.553	14.125	18.064	16.78	13.494	20.848	25.624	11.78	12.884	6.80
Carbonate of magnesia	1.134	1.390	2.750	9.030	1.89	6.750	10.428	11.025	....	6.442	8.97
Sulphate of lime	1.392	4.335	....	3.997	8.37	18.700	16.397	11.640	12.07	32.237	4.00
Sulphate of magnesia	....	....	3.160	....	8.4	....	....	4.000	1.95	....	....
Sulphate of soda	....	....	....	6.403	....	35.580	10.854	4.750	....	39.869	....
Chloride of magnesium	....	1.007	.660	....	....	....	....	....	12.63	....	....
Chloride of sodium	....	....	....	4.142	6.09	19.650	44.925	13.000	37.04	1.460	.82
Total solids in grains per gallon	9.165	12.115	20.695	41.636	34.56	95.004	105.732	72.324	76.08	95.810	21.49
Pounds caustic lime per 1000 gallons	.650	.650	1.840	3.040	2.82	1.700	3.520	3.980	.94	2.140	1.71
Pounds soda ash per 1000 gallons	.130	.640	.480	.440	1.08	2.070	1.820	1.800	3.58	3.580	.61
Approximate cost in cents per 1000 U. S. gallons	.350	.840	1.090	1.450	2.02	2.640	2.700	3.130	3.90	4.290	1.03

If the length of time between boiler washings can be increased eight or ten times over what was necessary before softened water was used and regular blowing down put in practice, and if it is found unnecessary to use scrapers or tube-cleaning machines at all, because no scale accumulates or builds up; if open exhaust steam heaters can be run from six months to one year without cleaning; if no live steam purifiers are required, and no boiler compound used, then by the use of softened water the percentage of idle capital is decreased, and the labor of cleaning boilers, heaters and purifiers is decreased.

A well-known engineer recently remarked: "We are far behind European steam users in taking advantage of the economy possible by keeping the interior of our boilers clean and free from corrosion." However, inasmuch as an increasing number of water-softening plants is being installed and successfully operated, we will soon lose our foreign reputation of being non-progressive in this respect.

But it must be borne in mind that the success of a water-softening plant depends upon the way in which it is operated. Therefore, the element of risk attending this part of its success should be as low as possible, and it has been demonstrated that the operation of the intermittent type is attended with less risk than that of any other.

ON THE ENGINEERING DIFFICULTIES ATTENDING A PROPER INSPECTION OF CEMENT.

By J. F. Coleman, Member, Louisiana Engineering Society.

[Read before the Society, April 8, 1901.*]

In the various and multiform details which make up the duty of the engineer, a proper and intelligent inspection of the materials which enter into the structures built under his supervision is far from being the least.

In harnessing nature to the service of mankind he makes use of so nearly all of the products of mine, quarry and forest, in natural and in manufactured form, that it would be too much to expect that any one individual member of the profession could be qualified to pass judgment upon all of them except in a most general way, and largely for that reason we have become subdivided into various branch professions; and as the world grows on, and we grow with it, there will naturally follow resubdivisions, so that each class of works and materials, within certain limits, will of necessity have to be in the care of specialists in that class.

However, there are materials so generally used in nearly all classes of engineering work that each man of us all, in whatsoever special branch he may be, should have a working knowledge of them, for the reason that he is compelled from time to time to make use of them under circumstances which frequently preclude the possibility or feasibility of obtaining the judgment of others more experienced than himself. To one of these materials this paper would direct your attention.

Cement is a building material which has been in use for so many centuries that it may almost be said to be older than the engineering profession. With its proper mode of manufacture this paper has nothing to do, nor with its proper use. It would be presumptuous likewise to claim that this paper can throw new light on the testing question. It is intended only to convey to you an idea of the difficulties that have been and are being met by the writer in the testing and inspection of cements, with some few statements of what appear to him to be facts in connection therewith.

At first glance it would appear that concerning a material so old as cement our knowledge should be absolute and our data precise, and the beginner will no doubt think such to be the case until he has gone below the surface into the subject. After that, each step he takes, each new piece of information gained, each experi-

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ment he makes, will but serve to make him doubtful of that which he thought was certainty before; and the deeper his research the less sure he will feel of his knowledge and its reliability. At least that is the experience of the writer, who has had more or less to do with cements for some ten or twelve years past, and who has carefully studied everything he could lay his hands on pertaining to this subject for the past five years, to say nothing of some laboratory practice.

Volumes enough to fill a large library have been written on the testing of cements. The various European countries have so-called "standard methods" for making tests, and we of America have also a standard. The subject has received for years past, and is receiving now, the best attention and most earnest study of the brightest minds in our profession in all countries. Nearly all the prominent engineering societies on the globe have standing committees on "cement," which make a special study of all the questions that relate thereto, collect all the writings on the subject and from time to time submit reports of such conclusions as may have been reached. And yet, with all this study and research, with all the literature on the subject from the pens of eminent engineers and others, the more deeply the writer has gone into this subject the less certain has he been of his conclusions or of the reliance to be placed in them, and the more "at sea" has he felt on the subject at large.

It should be understood, of course, if it is not already apparent, that this paper does not purport to be the work of one who lays claim to expert knowledge on the cement question, but is rather an *exposé* of the doubts and tribulations of one whose practice is not specialized in cement works particularly, and who therefore pretends to only an average amount of information on this important subject.

We all know, or can learn in very short order by reference to any one of the numerous text-books, the chemical constituents of the cements of the various classes. We know that the chemical analysis of one brand of cement of a given class varies somewhat from that of another in the same class, and that the analyses of the various classes are sufficiently marked to define them without serious trouble. We all have a general knowledge of how cements are manufactured, and we also know the approximate relative values of the several classes of cements; but there is not one of us who does know or who can absolutely determine the value of any given cement from a chemical analysis and a physical laboratory test occupying a reasonable time. There seems to be *no* test whereby the actual value of a cement may become known except the test of

usage and time, and in this respect each of us is dependent largely on his brother professionals.

If a sample of any unknown cement, no matter how valuable it may ultimately prove, be submitted to any engineer for use in an important structure, he would doubtless decline to admit it, irrespective of its chemical analysis or physical test. There is no question in my mind that he would be wise so to do, because of the dearth of any positive knowledge which would enable him to determine its value from any test that has yet been devised for laboratory use.

This lack of knowledge leads to a certain crudity in our specifications. For example, we require certain "fineness" tests, "tensile" tests, etc., but after these are all met by any sample of cement which may be submitted, we are still uncertain as to the merits of that cement unless we know that it has stood the test of usage and time, and that the laboratory tests of the same cement in the past have about coincided with the current test.

Cements have been manufactured that would pass the usual specification requirements and yet be unfit for use. Our tests not infrequently show better results for an inferior cement than for its superior. Samples taken from the same barrel of cement and sent to a dozen of the most accredited laboratories will show widely varying results. Briquettes made by two different men in the same laboratory, in as nearly the same manner as possible and from the same sample, will show considerable variation; and even those that are made by the same man from the same sample and at the same time have such a range of variation as to be bewildering to the seeker after certain knowledge. Of course it goes without saying that for any proper inspection of cements the engineer must be equipped with a testing machine, sieves, molds, etc., so that he may mold briquettes and break them as set forth in all the articles, papers and books that have treated the subject. The trouble is that after he shall have thus provided himself he has but opened new difficulties and doubts for himself. I know of a case in point: A sample was taken from packages of cement which were proposed for use in a certain piece of work. The engineer in charge was not personally acquainted with the brand, though he had heard of it, and it was well recommended to him by other engineers who had used it to their satisfaction. The cement was what is known as "natural," the specifications for which required, among other things, a tensile strength of 125 pounds, neat on seven-day test. The sample tested to 225 pounds under these conditions; the twenty-eight-day test was parallel, and the other tests set forth in the specifications were as fully met. The cement was admitted to use,

and was incorporated into part of the work under proper and careful inspection. In a short time it gave evidences of failure, and on being exposed showed practically no bond. Shortly afterward, the cement having been continuously used meantime on adjacent work which was under the supervision of another engineer and pronounced satisfactory by him, the gentleman whose experience I cite concluded to go further into the merits of this particular cement, as he had a great deal of confidence in the judgment of several of his brother engineers who had used it and pronounced it satisfactory; so he gathered new samples from a number of packages, divided the samples into several different parcels and sent them to as many different laboratories, requesting each of them to make thorough tests and to report not only the physical results, but the general conclusions arrived at. The laboratories referred to in due time reported most favorably on the cement. The test made anew by my friend on a part of the same sample showed results as nearly similar to his original findings as it was reasonable to expect; but upon again using the cement in question—this time under the most rigid personal inspection and with constant and careful continued testing—no better results were obtained. In this particular case the seeker after knowledge was no nearer the truth than he had been at the beginning, except that he had learned that the brand in question was unsatisfactory to *him,* in spite of the laboratory showing. On this state of affairs a difficulty arises. Here is a cement presumably manufactured and sold in good faith; it fulfills all requirements, in so far as laboratory tests go. That class of cements is a proper class for the work in hand, as evidenced by the fact that another brand of the same class, which does not stand the same laboratory test quite as creditably, is used in place of the rejected brand in the structure in question and does not fail. Other engineers who are without fear and without reproach use the brand and are satisfied with it, and yet it does not in *his* judgment serve its purpose at all. His conscientious judgment dictates its rejection, and yet he feels alone, or nearly so, in his position. He doubts his own conclusions, fears to do injustice to and work hardships on the manufacturer or dealer, and yet cannot conscientiously permit the use of that brand; all the while admitting that it fulfills all the specification requirements.

Now, for what purpose are engineering specifications intended? Is it not a fact that the engineer, by his plans and specifications, should seek to describe as accurately and completely as possible the work they cover in general and in detail, the manner of its execution and the matter with which it must be executed, the classi-

fication of materials, etc.? Does he not seek to describe the materials in such manner that there can be, in the mind of the bidder, no doubt as to what is intended in order that the bidder may intelligently estimate the cost of the work; and, further, that there can be no difference of opinion as to the intent between any two persons who understand such instruments of the engineer or architect as plans and specifications?

Whenever the specifications for any piece of work fail to so describe a given material as not to admit of a doubt as to what grade will be acceptable, they do not serve their purpose; and whenever such description as may be set forth in any specifications will clearly permit the use of a material which is unsatisfactory, that description is faulty.

We are but too willing and too prone to blanket over such imperfections as this last with the phrase "acceptable to the engineer," although in so doing we but stumble into the other fault mentioned; for who but the engineer can say what will be acceptable to him? In those materials concerning which we do have or can obtain absolute knowledge there can be no excuse therefore for such laxity of specifications, but there does seem to be some reason for it when we touch upon cement. Although such practice is far from infrequent, in the judgment of the writer it is not ethical in general to specify the "XYZ cement or equal," inasmuch as it makes a standard of a trade product manufactured by one concern. On the other hand, if we but specify that the cement shall be of a certain fineness, certain tensile strength, neat and sand, in specified time limits and the other usual requirements, without the saving clause "of a brand acceptable to the engineer," we bind ourselves tentatively to accept some new brand of unknown durability and value purely on a laboratory test, which, after all is said, counts for very little. Again, the results of different laboratories on the same sample vary so widely that when a cement is *near* to the requirements, either above or below in your own laboratory it may show far above or far below in some other laboratory; or if two or more be called on to test, one may be considerably above and another as much below your own results.

On one brand, for instance, some eighteen tests, made by four laboratories, on neat cement, seven days, ranged from 186 to 576 pounds. This is a very unusual and extreme case, but a difference of 150 pounds ranging between 350 and 500 pounds is by no means as rare as might be supposed. With such a state of affairs the engineer must bring his best judgment to bear on the cement question in order to get results; he can be bound by no cast-iron rules.

He must sometimes reject cements that fill the requirements of the specifications, and on some other occasions he could safely admit a cement that fails to come within the said requirements. Our specifications, then, are not precise and clear, but are merely a rough guide, and will so continue until such time as we have obtained more absolute knowledge.

For comparison and analysis I have formulated a tabulation showing the chemical analyses of five different cements, to which I would invite your attention:

<table>
<tr><th rowspan="2">Constituents.</th><th colspan="3">Domestic Portland.</th><th colspan="2">Slag.</th><th>Portland.</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><td>Silica</td><td>20.76</td><td>21.80</td><td>21.48</td><td>28.85</td><td>22.80</td><td>22.50</td></tr>
<tr><td>Oxide of iron</td><td rowspan="2">10.71</td><td>3.93</td><td>2.70</td><td rowspan="2">12.05</td><td>1.55</td><td>3.50</td></tr>
<tr><td>Alumina</td><td>7.23</td><td>7.74</td><td>14.10</td><td>7.00</td></tr>
<tr><td>Lime</td><td>63.42</td><td>63.12</td><td>62.22</td><td>51.20</td><td>46.10</td><td>61.00</td></tr>
<tr><td>Magnesia</td><td>2.89</td><td>1.88</td><td>2.95</td><td>2.27</td><td>3.65</td><td>1.25</td></tr>
<tr><td>Sulphuric anhydride</td><td>1.67</td><td>1.17</td><td>1.75</td><td>1.31</td><td>1.40</td><td>0.88</td></tr>
<tr><td>Loss on ignition</td><td>0.55</td><td>0.54</td><td>0.27</td><td>4.05</td><td>7.40</td><td>2.82</td></tr>
</table>

Nos. 1, 2 and 3 are domestic Portland cements; Nos. 4 and 5 are slag cements, and No. 6 is the average formulæ given by Candlot & Spalding for Portland cement. It will be noted that Nos. 1, 2, 3 and 6 do not vary very widely as to chemical constituency, and that the principal chemical difference between them and Nos. 4 and 5, which are slag cements, is that the latter run high on silica and low on lime.

Now let us compare Nos. 2 and 3, both Portland cements. These show very little difference, and that little would hardly seem to account for a difference in physical test. Records of No. 2 show an average tensile strength of 850 pounds neat on seven-day test, while No. 3 only shows 700 pounds. No. 3 is a well-known brand that has been in extensive use for a number of years; No. 2 is comparatively new, having been in use for only a few years. Both are usually acceptable brands, and yet I have been reliably informed within the past week that this No. 2 has recently been rejected by a most painstaking and experienced engineer for the work under his charge for reasons not stated.

It is plain that we cannot all be experts on cement or on any other one material; and if we are not experts, how can we pass intelligently upon the merits or demerits of the material before us?

It is an "old saw" that "a little knowledge is a dangerous thing," and while that saying is always more or less trite, it seems to be particularly so here.

Under present conditions we are likely to reject a good cement and use a poor one, and never learn that we have erred until too late to rectify the error.

As a broad general proposition, it might be stated that the only safe way to act on works of supreme importance would be to admit only brands of high standing that have been well known for years; to assure ourselves of the freshness of that which is used, and to test physically from time to time in order to assure ourselves that the cement has not been tampered with. An objection to this plan is that a virtual monopoly would be effected, since if all engineers followed this line it would not pay to establish new factories and to create new brands. The progress that has been so marked in the character of Portland cement in the past few decades would also be checked, as there would then be no incentive to improve or to seek to improve the present standards.

There is no reason to hesitate in prophesying the course of the profession on this question. We will continue in the future to do as we have done in the past, and occasionally, when circumstances and surroundings justify it, will "take chances" until the happy time arrives when the laboratory experts devise some sure and certain method of classifying cements by their tests so that the relative values may be absolutely gauged, without regard to brand or other trade-mark and without regard to past performances. In the meantime we may all at least hope that such a time is near at hand.

DISCUSSION.

Mr. L. W. Brown (by letter).—The variation of 50 per cent. or more referred to by the author between different laboratory tests of the same artificial cement is, to my mind, due to want of ordinary care on the one hand and to extraordinary care on the other in the manipulation and care of the briquette; and it may be observed that with the greatest care a difference as high as 20 per cent. will result between two laboratories testing the same artificial cement, due to difference in method of manipulation. But the great differences referred to unquestionably result from the improper and careless manipulation of the briquette, which is perhaps the most important part of the test and which is often done by the office boy or janitor.

I am of the opinion that if an engineer wants accurate knowledge of the cement he is using he must personally test it, and an engineer in charge of large and important works should be equipped and required to make these tests so as to nullify the element of carelessness and secure uniformity in manipulation. But such tests are

more for the satisfaction of the engineer than to secure any valuable results.

The value of laboratory tests was most clearly illustrated during the construction of portions of the drainage work in New Orleans, where the Drainage Commission arranged with Professor Creighton, of the Tulane University, to make the tests. As often happens, the results of the test were not made known until after the lot from which samples were taken had been used in the work, and when the results showed deficiency the work suffered; from which conclusions I feel justified in advancing the opinion that the testing of cement as it is used cannot result in any benefit, and may be the cause of serious trouble.

The American Society of Civil Engineers has for several years past endeavored to reach some standard for testing cement, but has as yet reached no definite conclusion; and the subject has received the deep consideration of the best minds in this country and in Europe. The conclusion reached is that the testing of cement embraces conditions wherein the slightest variation in manipulation causes wide difference in results, and the manipulation does not admit of the precision necessary to secure a satisfactory standard, as will be readily observed by the following parts of the manipulation wherein variation occurs:

How are samples obtained, and from what proportion of packages?

How are the samples mixed?

Proportion of samples made into briquettes.

Depth, diameter and size of wire of screen.

Length of time screens of different finenesses should be shaken.

Humidity of atmosphere.

Temperature.

Amount of water, and whether regardless of humidity of atmosphere.

Pressure in forming briquettes.

Fineness and angularity of sand.

Method of mixing.

Length of time the mixing should continue.

Method of filling the briquette frame.

Treatment of briquettes while setting.

Surface on which briquettes are formed.

Finish of briquettes, by trowel or otherwise.

Rate of applying load.

From this it is most apparent that no positive standard for laboratory tests can be made which will give any reasonable

uniformity of results. Hence other measures must be thought over, considered and, if satisfactory, adopted; and I would submit the following,—viz:

Artificial or Portland cement is susceptible of the same class of inspection at the factory as is steel, iron or machinery at the mills, foundry or shop. The proportion of the ingredients can be and are by the factory chemically determined in the slurry before burning, and the fineness is regulated by screens as the finished cement leaves the stones. The proper chemical analysis being determined, as also the fineness for certain results, the factory should sell the cement according to these different and known ingredients, coupled with the fineness, and the price proportioned to the value of the contained ingredients and their fineness. The engineer specifies the class of cement, and in the case of large works he places a competent man at the factory, the same as he does at the rolling mills, foundry or shop. The sack or barrel containing the cement of proper requirements is labeled and sealed, and if the seal is broken before reaching the work the cement is rejected. When the amount of cement required is small, arrangements can be made whereby the dealer, at small additional expense, has the cement inspected, labeled and sealed by any of the several reputable inspecting and testing firms.

The results from such inspection would far exceed in value any laboratory tests, and would remove the main difficulty attending the use of cement. The factory must necessarily give an absolutely true statement of chemical ingredients and fineness for the various strengths of their particular cement.

As to natural cement, it is understood that the product cannot possibly be uniform, and consequently it is not expected. Hence natural cement, no matter how satisfactory a test may be shown, should not be used on work where great stability and longevity are required.

The fluctuating value of cement is very largely occasioned by the manipulation of the mortar on the work where it is used, and is often the cause of failure of good cement; and it is obligatory, in order to secure good results, that the engineer should have means to ascertain positively the manipulation of not only one batch, but of every batch used on the work. The main points to be secured to provide good results in cement masonry or concrete are the angularity, fineness and proper proportions of sand and the proper amount of water. Too much water drowns the cement, and if applied in large quantities or under pressure has a tendency to separate the cement from the sand, so that the proper mixing is not

secured. The chemical analysis of the water should be known, and turbid water, carrying clay in suspension, should not be used. Thorough, complete and uniform mixing of the sand and cement is also very important. In fact, a poor cement properly manipulated will give better results than a good cement improperly manipulated.

EARLY TRANSPORTATION CANALS.

By J. T. Fanning, Member American Society Civil Engineers.

[Synopsis of a paper read before the Engineers' Club of Minneapolis, April 15, 1901.*]

We sometimes hear that canals are now obsolete, but at the last sessions of our National Congress there was offered a resolution relating to a proposed canal. That resolution, if passed, might have awakened a thrill among the nations like that of a proclamation of defiance to the world. Recent foreign news items have indicated that the German Government has considered most earnestly the desirability of constructing additional extensive canals, and also that the Russian Government has now in progress a canal intended to connect the Gulf of Riga and the Black Sea, a work not less in magnitude as an engineering work than is her Siberian railway. It is only about two years since Vice-President Roosevelt, then Governor of New York State, desiring to formulate and recommend a canal policy for the State of New York, appointed an eminent commission, and said to them:

"I desire the opinion of a body of experts, who shall include in their number not merely high-class engineers, but men of business, and especially men who have made a study of the problems of transportation; who know the relative advantages and disadvantages of ship canals, barge canals and ordinary shallow canals; who are acquainted with the history of canal transportation as affected by the competition of railroads, and who have the knowledge that will enable us to profit by the experience of other countries in these matters."

These suggestions indicate that the question of useful canals is still a living issue and indicates that the charge of obsoleteness applies only to those canals whose usefulness has been outgrown through lack of their capacities. On close examination some of those old canals are found to have been stupendous works, which, for their day, were most creditable to their promoters, and may even now excite our admiration. They are, therefore, of historical interest.

Here followed a concise historical sketch of the *ancient lowland canals* constructed and used by the Chaldees, the hydraulic works of the Egyptians and the colonial hydraulic enterprises of the Romans.

Sluice Chutes.—If we keep in remembrance the fact that the early transportation waterways were without locks, and that sluice

*Manuscript received May 31, 1901.—Secretary, Ass'n of Eng. Socs.

chutes were used as substitutes for locks, we shall see clearly that those waterways could have been only works of the deltas and low countries. The Chinese have not yet modern locks on their grand or other canals, but they are said to pull their boats from one level up to slightly higher levels by the aid of windlasses, and with much expenditure of manual labor. Instead of locks they have guide walls at each chute, narrowing the canal to the width of their widest boats, and they use stop planks or timbers at the downstream end of the changes of canal levels and open the chute when a boat is to pass. This was the method in use in Italy before the idea of a gate at the upper end of the lock was conceived.

Straight-Edge Levels.—The old excavators of canals had not the advantage of a spirit level to aid them in laying out their works. The Romans are said to have used, in leveling, the straight edge of a plank about twenty feet long. At each end of this plank a frame depended, and on each frame a line was made at right angles to the top of the plank. While in use, the plank was so adjusted that plumb lines hung from the top of the plank would cover the vertical lines on the upright frames. The top edge of the plank was then level and could be used for sighting. In the top edge of the plank was a groove which was sometimes filled with water, and when the water was equally near the top edge of the plank at the ends, the plank was sighted along for a level line.

Canal Locks.—The invention of the second or upper gate, in connection with a canal chute, embodied the principles of construction of the modern lock.

This invention is claimed in Italy for two brothers Domenico, in 1481, and the State of Venice has claimed to have been the first to adopt the double gates. It is said that Leonardo da Vinci, famous as painter, architect, philosopher and engineer, adopted the Domenico scheme to connect two canals in Milan, by six locks with a total fall of 34 feet, and he has since often been mentioned as the inventor. He may have first so planned a lock that it became a practical and useful invention.

This lock, with upper and lower gates, marks a distinct advance in canal engineering; for canal boats that had heretofore been of service in the low and nearly level countries might now rise to the higher lands and proceed farther inland, and might even cross ridges of moderate height from stream to stream and from estuaries to elevated inland lakes.

To the Italian philosophers, Galileo, Castelli, Toricelli and their pupils we are indebted for much of the early experimental knowledge relating to the flow of water through orifices and small pipes

and over weirs, and for the early formulas developed from their researches; and, likewise, we are indebted to the Italian engineers for the methods of practical construction of transportation canals, on which boats might ascend from the lower to the upper part of a river valley.

The broad lower valley of the River Po, extending from the foot of the Alps on the north to the foot of the Appennines on the south, was in early times covered with a network of irrigation canals, and this valley became in consequence the fertile garden of Northern Italy. When the true canal lock was invented, the canal system extended up the valley of the Po above the city of Milan, and the Italians became the most skillful canal builders in Europe.

Foreign Canals with Locks.—In 1758 the English Parliament granted to the Duke of Bridgewater an act for the construction of a transportation canal between Manchester and Liverpool, and this canal was constructed under the direction of the eminent engineer Brindley. It is recorded that, in the middle of the last century, the cost of transporting goods by road between Liverpool and Manchester, about thirty miles, was forty shillings per ton, or about thirty-three cents per ton per mile. The Bridgewater canal reduced this rate to six shillings, or about five cents per ton mile. The result gave a tremendous impetus to manufactures and to mining in England, and started England on a period of most remarkable commercial prosperity that placed her in the front rank of manufacturing nations.

Following this beginning of water transportation from the Mersey harbor, England soon developed an extended canal system, opening important lines of internal navigation in various parts of the United Kingdom.

The Royal and Grand Canals in Ireland, ninety-two and eighty-five miles in length respectively, were originally works of much importance. They extended from Dublin, on the east, to Limerick on the west of Ireland.

The prominent industrial advancement of Belgium was largely due to the promotion of cheap water transportation. Belgium has maintained its principal waterways, and still derives great advantage from them. From Brussels, the capital, which is near the center of the state, there is even now a regular line of steamers to London.

Holland was known as the "Land of Dykes and Ditches" before she began to embank her lowlands from the sea. Her ditches still serve as public thoroughfares for navigation in summer

and for sledges and for skaters in the winter. The Haarlem Canal, surrounding the Haarlem Meer, a lake of about seventy square miles area, was originally excavated to facilitate the drainage of the Meer, and to furnish a transportation route to replace navigation upon the lake. The canal surrounding the lake is thirty-eight miles in length. Into this canal the waters of the lake were pumped with an average lift of sixteen feet, and the rainfall is still pumped into the canal. This area of seventy square miles is redeemed from below sea level for the benefit of agriculture and the enrichment of the state.

The canal works of the French engineers present some of the most scientific and substantial hydraulic constructions for transportation purposes of the early as well as of modern times.

The German and Russian engineers have also executed, in their respective countries, some important transportation canals that are worthy of special attention, but our time will not permit reference to them in detail.

Gustavas Vasa, in Sweden, is said to have been not less ambitious for the development of the resources of his state than was Peter the Great for the development of the internal resources of Russia. It was his desire that there should be continuous water transportation from Gothenburg, on the west, to Stockholm, on the east. Along the proposed route are the lakes Wener, Hielmar and Mælar, whose connecting streams have great cataracts. Several successive rulers, after Gustavas, examined anew this navigation project and partial works were undertaken from time to time. In 1806, Thomas Telford, the experienced and famous canal engineer of England, was called to examine and report upon the whole project. Telford's comprehensive plan was adopted and the work commenced. Sixty-five miles of the line required artificial work, and the remaining fifty-five miles were lake navigation. The summit of the canal is 296 feet above tide level. The plan showed 42 feet width of canal at the bottom and 10 feet depth of water. The locks were planned 120 feet long and 24 feet width. This was justly regarded as one of the most important public works in progress in the first decade of the late century, and this canal is still in service.

The Swedish Canal, connecting the Wener and Wetter Lakes, is of nearly equal importance as respects remarkable construction and extent of traffic.

American Canals.—Our own Washington, the surveyor and engineer, when a private citizen of Virginia, exerted a strong influence and gave his best endeavors to inaugurate a comprehensive

system of American internal routes of transportation both of public roads and canals.

As a surveyor, as promoter of the interests of his State, and then, in 1754, as commander of a military expedition, he became familiar with the trails from Chesapeake Bay and James River over the Allegheny Mountains to the Ohio River Valley, and with the portages from the Hudson River along the Mohawk and Oswego Valleys to Lake Ontario. Before 1776, a considerable migration of families from the Atlantic Coast colonies had started toward the fertile lands west of the mountains. The war of Independence then interfered with the advancement of projects for public highways. Soon after the close of the Revolutionary War, Washington is said to have obtained a charter for a water route between the Hudson River and the Great Lakes, and was elected the first president of the company. This was, however, but one of the efforts that later led the State of New York to undertake the greater waterway along a similar route.

At the opening of the new century, the farmers who had migrated from Massachusetts to Vermont were sending their produce to Boston by way of the Merrimac River, and the farmers who had migrated to lands known as Central New York were sending their produce to market by transports down the Delaware and Susquehanna Rivers in frail boats which were not expected to be returned up the rivers.

In 1805 Congress appointed three commissioners to search for the shortest and most desirable route for transportation over the Alleghenies, and, in 1808, Albert Gallatin made an exhaustive report to Congress upon the topography of the United States, and suggested a network of rivers, canals and roads, to be improved by the central government.

The necessity of cheapening transportation was at the same time suggesting private development of waterways by chartered companies.

The American canal-building era began with starting the constructions of the Middlesex Canal in Massachusetts and the Santee Canal in South Carolina in 1802. The Middlesex Canal was completed from the Charles River at Boston to the Merrimac River near Lowell in 1808. The era of the construction of old-style transportation canals continued until about the year 1840, at which date about 4000 miles of canals had been built in the United States, beside the important canal works of Canada.

In the New England States there were 227.69 miles of canal, of which the Middlesex, thirty miles long, and the Blackstone,

forty-five miles long, were most important. These two have gone out of use.

In the remaining Atlantic States there were 2526.77 miles of canals, of which the Erie, 363 miles length, and its branches, 365.75 miles in length, were the most important. The Erie Canal was commenced in 1817 and completed in 1825.

There were also, in the Atlantic States, the Delaware and Hudson Canal, 119.63 miles length; the Raritan, 42 miles; the Morris and Essex, 101.75 miles; the Lehigh, 84.48 miles; the Chesapeake and Ohio, 136 miles; the James River, 175 miles; the Dismal Swamp Canal, 23 miles.

A large part of the canals above enumerated are still useful in the transportation of heavy freights.

In Illinois there is the Illinois and Michigan Canal, on which there is still traffic.

In Indiana there is the Wabash and Erie Canal, 187 miles in length.

In Ohio there is the Ohio and Erie Canal, 307 miles in length; the Hocking, 50 miles; the Miami, 178 miles; the Sandy and Beaver, 76 miles; and the Mahoning, 77 miles in length.

Ohio, Indiana and Illinois have a total of 1086.9 miles, while Alabama and Louisiana have together 151 miles of canals.

The Pennsylvania system, extending from the head of the Chesapeake Bay to Pittsburg, was a combination of canal and railway, and that part between Harrisburg and Pittsburg was substantially adjacent to the route now followed by the Pennsylvania Railroad.

The Schuylkill and Lehigh systems were essentially slack-water navigations, involving many dams in the rivers and locks at the dams.

The Erie Canal and its branches, as first constructed, had generally a surface width of 40 feet and depth of 4 feet, and locks of 90 feet length and 15 feet width, and accommodated boats of 80 tons burden.

The Lehigh had a depth of 5 feet and locks 100 by 20 feet, and accommodated boats of 100 tons.

The Chesapeake and Ohio Canal had a depth of 6 feet and locks 100 by 15 feet, and accommodated boats of 150 tons.

The Illinois and Michigan Canal had a depth of 6 feet, and accommodated boats of 150 tons.

The Erie has been twice enlarged, and the New York State authorities are to-day discussing the proper amount of appropriation, whether $22,000,000 for another moderate enlargement or

$62,000,000 for a considerable enlargement of the Erie Canal prism and locks.

In January, 1900, the eminent New York State Commission, already mentioned, reported on two projects of enlargement. One project proposed to deepen the canal prism to 9 feet and adapt its locks to pass boats of 450 tons burden, at a cost of $21,161,645, and the other project recommended was to deepen the prism to 12 feet and increase the locks so as to pass boats with a cargo capacity of 1000 tons each, at a cost of $58,894,668.

The commission suggested pneumatic or other mechanical lifts at Cohoes and Lockport, as substitutes for the groups of locks at those sites.

Our limitations as to time permit only brief mention of the Canadian Lachine, Welland and Sault Ste. Marie Canals, because they should be classed among ship canals, and therefore not strictly within our present province. For the same reason we can only mention in general terms the American Sault Ste. Marie Canal, which surpasses all others in dimensions of locks and in amount of traffic.

Slide Gate Locks.—One of the first American examples of rolling lock gates was completed, in 1885, at the Davis Island dam on the Ohio River, five miles below Pittsburg. The lock is 600 feet long and 110 feet wide. Each gate is opened by rolling it into a pocket at one side of the canal. A quadrant gate is proposed for the head gate of the lock on the Mississippi River between Minneapolis and St. Paul. This gate is 80 feet wide, and is to be raised by pressure from the water above the lock, somewhat after the manner of operating bear-trap dams.

Inclined Plane Lifts.—For nearly three hundred years after its invention, in Italy, the two-gate lock was uniformly adopted in new canal constructions. Then inclined planes were introduced in a few high lifts. A conspicuous example in our own country is on the Morris and Essex Canal in New Jersey. This canal extends from the Jersey Flats through Newark and over the hills to the Delaware River at Easton. This canal has 23 inclined planes, with average lift or fall of 58 feet, thus covering 1334 feet of rise and fall, while an additional 223 feet of rise and fall is overcome by locks of low lift. The boats constructed for this canal were 8½ feet wide and 60 to 80 feet long, and of 25 to 30 tons burden, but not exceeding, with maximum load, 50 tons weight.

There were twin-lock chambers at each end of the incline, and a track similar to a railway track extended through the lower locks up the incline and through to the end of the upper locks. A truck,

similar to a railway platform car, but lower, was run into the lock before the boat entered. This truck was nearly as long as the boat, and rested at each end on a group of four flanged wheels. On top of each side of the truck floor was a truss to stiffen the floor. This truss extended a little higher than the gunwale of the boat. After the boat had entered the lock, it floated over the truck and was made fast to it. A chain, securely attached to the frame of the truck at one end, extended over a windlass at the top of the incline and to the twin truck. By aid of power, applied to the windlass, the car and boat were quickly hauled up or lowered down the incline, when the water floated the boat off from the car and the boat proceeded on its regular journey.

On the Chesapeake and Ohio Canal, an inclined plane high lift was constructed to pass boats from and to the Potomac River. This was located about one mile above Georgetown, and was of lift equivalent to the five locks at Georgetown.

The Monckland Canal, near Glasgow, has a conspicuous example of an incline sloping one in ten, and with a vertical lift of 98 feet. Each truck runs on twenty wheels, and its tank is 70 feet long, $13\frac{1}{3}$ feet wide and $2\frac{1}{4}$ feet deep. The weight of each carriage, with water and boat, is about 80 tons, and two are used, counterbalancing each other.

In the overland canal in Germany there are inclined planes on which boats of 50 tons weight are handled.

Another class of canal inclined planes in Germany is known as Greve's Lock. This consists of two inclined channels, side by side, sloping 1 in 10, with very smooth walls and floors. This double channel unites two canal levels, and has gates at the upper level. When a boat is to ascend, it is first floated into the foot of one channel, then a movable valve, mounted on wheels and of the full cross-section of the channel, moves up behind the boat and crowds forward a sufficient mass of water up the inclined plane to float the boat to the upper level. At the same time a floating boat may be similarly lowered in the twin channel. The two valves are connected together by a chain which passes over a windlass at the head of the incline. A small surplus of water on the side of the descending boat overcomes the frictions of the moving valves.

Canal Aqueducts.—The Chirck aqueduct, on the Ellesmere Canal in North Wales, is an excellent example of bold and skillful engineering. This work was planned by Telford, and was completed in 1811. This granite arched aqueduct of 10 spans and its high embankments cross the valley of the Ceriog River where the

valley is 700 feet wide. The water surface in the aqueduct is 70 feet above the level of the river.

The Dee aqueduct, on the same canal, is 1007 feet in length, and consists of an iron trough about 12 feet wide. This iron channel is supported by 19 arches and trusses on masonry piers. The surface of the water in the canal is 121 feet above the surface of the river.

The Seneca River aqueduct of the Erie system has 31 spans of 22 feet clear opening. The waterway is a timber channel 53 feet wide, with 6 feet depth of water. The tow-path is carried on 31 masonry arches.

On the Erie Canal there are two aqueducts over the Mohawk River. One of these is 1188 feet length.

The Genesee aqueduct, at Rochester, is of cut stone masonry. It is 804 feet long and has 11 arches.

The Delaware and Raritan Canal has 12 aqueducts, and the central and western divisions of the Pennsylvania Canal had a total of 49 aqueducts.

Canal Tunnels.—On the Leeds and Liverpool, in England, there is a tunnel 4920 feet long, 18 feet high and 17 feet wide.

On the Birmingham Canal there are several tunnels having an aggregate length of 6¼ miles.

There are several short tunnels on the American canals, and the layout of the Chesapeake and Ohio Canal contemplated a summit tunnel 3¾ miles long, passing through the crest of the Allegheny Mountains.

Canal Dams.—The Schuylkill River slack navigation involved the construction of 34 dams. The central division of the Pennsylvania Canal required 18 dams, and other American canals and their feeders have required numerous dams, some of them expensive.

Hydraulic Lifts.—Hydraulic lifts are another substitute for locks on transportation canals, and they have proved successful and are especially valuable as savers of lockage water and of time in lockages when there are great differences of level between two sections of the canal. One of the first successful lifts was at Anderton in England, for connecting the river Weaver navigation with the Trent and Mersey Canal.

In this lift tnere is a pair of metallic tanks, each of proper size to receive a canal boat and the water to float the boat. Each tank is mounted on a long vertical plunger of 3 feet diameter. Beneath the canal bed is sunk a long cylinder into which the plunger enters through a stuffing box, so that the cylinder and plunger constitute

a hydraulic ram or lift which, in this case, can move vertically 49 feet.

When a boat is to pass from a lower to an upper level, one tank is lowered, so that its floor is level with the bed of the canal. Its end is opened and a boat floats into the tank. The end is then closed, and the boat, still floating in the water-filled tank, is lifted 49 feet to the upper level. The gate at the other end of the tank is then opened and the boat floats into the upper level of the canal. At the same time another boat may have been lowered in the twin tank. The tanks are so arranged that the weight of one balances that of the other. There is a group of guide columns at each corner of the double lift and the tops of the columns are connected together by stiffening trusses. A tank girder at the top level for each tank, connects the lift tank with the canal in the earth embankment. A small pumping plant, near the base of the lift, gives the hydraulic pressure equal to 38 atmospheres, which sustains the rams. A small surplus of water in the descending tank overcomes the friction, and this slight difference in weight is secured by drawing a small quantity of water from the tank which is to ascend. This Anderton plant was erected in 1875.

The Les Fontinettes lift, near St. Omer, in France, and the La Louviére lift, on the Canal du Centre, in Belgium, are similar in character to the Anderton, but are larger and have two hydraulic plungers for each tank. There are substantial masonry guide piers at Les Fontinettes.

The lift tanks at Anderton are 77 feet long and 15 feet wide. They have 5 feet depth of water, and lift boats of 100 tons burden.

The lift tanks at Les Fontinettes are 133 feet long and 17 feet wide. They have 6.6 feet depth of water, and lift boats of 300 tons.

The La Louviére lift tanks are 141 feet long and 18.4 feet wide. They have 8.5 feet depth of water, and lift boats of 110 tons.

Their rams are respectively 3 feet, 6.6 feet and 6.6 feet diameter, and their vertical lifts are respectively 49 feet, 43 feet and 55 feet.

In the "Prussman" lock it was proposed to support a lift tank on five or more submerged cylinders under the lock. These cylinders were air-tight and contained sufficient air to support and elevate the tank containing the canal boat to be lifted.

Pneumatic Locks.—The Canal Board of the State of New York proposed to use pneumatic locks in the improvement of the Erie Canal, and designs for such locks were prepared by Chauncey Dutton, C.E., in 1895, for the Cohoes lift of 144 feet, and for the Lockport lift of 57½ feet.

This system proposed also to employ metal tanks in which the boat is floated in water as it is elevated. The floor of the tank will rest on five or more inverted cylinders, like straight-sided bells, which are open at the bottom, but closed at the top by a tight connection with the tank floor.

When the lock tank is down, the hollow cylinders beneath the floor project into the water. When the lock tank is to be raised, air is pumped into all these inverted bells or hollow cylinders, which are so connected by pipes that there will be uniform pressure in all. The locks are in pairs, their pressure pipes are connected so that each may be equally buoyed, and each will sustain its tanks and floated boat. When the tank lifts are to change elevations, a little water is withdrawn from the ascending tank. A complete set of operating pipes is provided, with valves and controlling apparatus and with air and water pumps.

The proposed length of each boat tank is 310 feet, the water width 29 feet, and the water depth 12 feet. Each tank is expected to pass up, at one motion, two boats carrying each 1350 tons, or a total of 2700 tons of cargo, within ten minutes time between arrival and departure of the boats, and to pass down two similar boats at the same time.

Results.—The construction of canals has reduced costs of transportation of agricultural products and of merchandise of the lake districts from $0.25 per ton mile on earth roads to $0.00075 per ton mile along the water route which our Northwestern products now take to the Eastern markets.

These canal waters first made possible the full settlement of our lands on the western slope of the Appalachian chain, and then, together with lake navigation, made possible, by cheapening transportation, the settlements and agricultural developments of our Middle and Western States. In process of time they have made possible the sending of the grain and flour of the Northwestern to the Eastern States and to Europe.

These canals present some most admirable examples of skillful engineering. The story of the evolution of these American canals is also, in large part, the story of the evolution of the profession of civil engineering in America, and the record of our predecessors along this line is one to which we may turn with satisfaction, with professional admiration and with pardonable national pride.


DOMINION OF CANADA
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
UNITED STATES
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
MEXICO
GULF OF MEXICO
PACIFIC OCEAN
ATLANTIC OCEAN

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SUBAQUEOUS TUNNELS FOR GAS CONDUITS.

BY W. W. CUMMINGS, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, April 17, 1901.*]

AT the first of the year 1899, in the distribution of its gas, the Massachusetts Pipe Line Gas Company found itself confronted by the problem of three river crossings: The Mystic River at Malden Bridge, Charlestown near Everett; the Charles River at the new bridge between Charlestown and Boston proper, and the Charles again at the River Street Bridge between Cambridge and Brighton.

The size of the pipe at Malden Bridge was to be 54 inches, that at Charlestown Bridge 42 inches and that at River Street 48 inches. It was necessary to avoid "pockets" in the pipe, which would tend to obstruct the passage of the gas by the collection of water of condensation, and to provide for the removal of this drippage.

The pressure head in the tunnels, when passing gas, was liable to vary from 3 to 12 inches water column, *i.e.*, the problem was to keep the water out rather than the gas in.

The requirements of the State Board of Harbor and Land Commissioners were as follows: For the Malden Bridge the top of siphon must not be less than 23 feet below mean low water, and the clear width of draw opening must be at least 43 feet; for the Charlestown Bridge the top of siphon must not be less than 28 feet below mean low water, and the clear width of draw opening at least 50 feet; for the River Street Bridge the top of siphon must

*Manuscript received May 20, 1901.—Secretary, Ass'n of Eng. Socs.

not be less than 10 feet below mean low water, and the clear width of draw opening not less than 36 feet.

This gave a minimum cover of 7 feet at the Malden Bridge, and none whatever at the Charlestown Bridge or at the River Street Bridge, so far as the Harbor Commissioners were concerned. As a matter of fact, the legs of the siphons were placed farther apart than these requirements, in order to provide room for fenders and for working of the draw, while the least safe cover was about 8 feet of earth. It was also necessary to avoid obstructing the channel during construction.

It was necessary to take into consideration the future changes in these bridges, since, after once connecting the various gas companies, it would be disastrous to cut the supply.

This latter consideration barred the old Warren Bridge, located just above the new Charlestown Bridge, and rendered the River Street Bridge uncertain, while at that very time steps were being taken toward building, on the Malden Bridge site, a new structure, in which the location of the draw had a wide range of probability. The possible deepening of the channels had also to be taken into account.

At Malden Bridge a siphon in place would cost $14,000, and the approach on piles (800 feet in length) $15,000, fenders $20,000, a total of $49,000 from bank to bank. Bids were received from Charles Haskin for constructing a tunnel and laying the pipe for $33 per lineal foot, the material to be furnished by the pipe line company. This made a total of about $50,000 from bank to bank, as against $49,000 for the ordinary siphon. This difference in cost was more than balanced by the advantages afforded by the tunnel, which would be practically indestructible, independent of the changes in highway traffic and navigation, and free from liability to accident and need of repairs.

At the Charlestown Bridge two siphons would have been necessary, if constructed in the ordinary way, at a cost of about $24,000 and $10,000 for the extra fenders, while the bids for a tunnel under the two draw spans was $51 per lineal foot for driving the tunnel and $11 per foot for laying the pipe and concreting, all material to be furnished by the Massachusetts Pipe Line Company as before, making a total of $36,000, as against $34,000 for the ordinary siphons. At this time the advantages of a tunnel were so obvious that it was determined to use that construction here also.

About April 1, 1898, the Malden Bridge Tunnel was started with a time limit for completion set at August 1 the same year, and

contracts were made for the completion of the other two a month later, September 1 being the time set for turning gas into the mains. As a matter of fact the Malden and Charlestown Tunnels were completed about December 1, 1899.

Three methods were suggested in the design of the tunnels. In all of these the tubular casing by wooden lagging (a method originated by the contractor, Mr. Charles Haskin, and described later) was considered.

One plan was to line the lagging with brick masonry laid under compressed air, and to lay the pipe or pipes on blocking, free and open to inspection, repair and possible future additions. Had the fluid to be carried been water instead of gas, the convenience undoubtedly would have outweighed the possible extra cost. As it was, the advisability of avoiding anything that might be converted into a gas pocket prevented such constructions, while the rigidity of the structure was best obtained by making it one solid piece, as by filling the space between the pipe and the lagging.

In sinking the shafts it was proposed to use ordinary sheathing until the water should be reached, and from that point to sink a steel tubular casing by means of compressed air.

At the Malden Bridge wash borings were made and compared with those of the Metropolitan Sewerage Commission, which had driven a tunnel a few feet to the east. It might be said here that in all cases these borings, although made by a responsible firm, were chiefly remarkable for their unreliability.

The first shaft was sunk on the Everett side of the Malden Bridge, as near the abutment as the retaining wall would allow. After going about 6 feet, the steel caisson was erected and sunk in the ordinary way (see Plate A, Fig. 3), paving stones being placed on the shelf at *a* and the excavation carried on under the cutting edge *b*. The casing was kept plumb by varying the excavation and also by such guides as might be used at the top. The caisson was extended by removing the air lock and inserting a 10-foot section, caulking the flanged joints when necessary.

This shaft was 46 feet deep 43 feet below high water, at which times, of course, the air pressure was about 23 pounds.

The steel casing, shown also in Plate A, was made of ⅜-inch boiler plates riveted to a 3-inch angle iron, which, with the corresponding angle iron of the next section, formed a flanged joint that was made up with red lead and caulked where necessary. The inner diameter of the tubing was 7 feet and the length of a section was generally 10 feet, each section weighing about 4000 pounds.

The cutting edge was made on the first section by placing a wide flange 2 feet back from the bottom and staying it with brackets as shown at *a*. On this shelf the paving stones were placed, to balance the upward pressure of the air and to furnish a downward thrust at the cutting edge. Stones, piles, sunken timber, etc., were broken up and taken out through the lock.

When material sufficiently compact to prevent the escape of the air was reached the sinking of the caisson was stopped, and the lagging was carried down the shelf, as shown in Fig. 4, Plate A.

This lagging consisted of circular segments 6 inches wide, sawn from 2-inch plank and having an outer diameter of 7 feet. There were eight of these segments to a ring, and they were

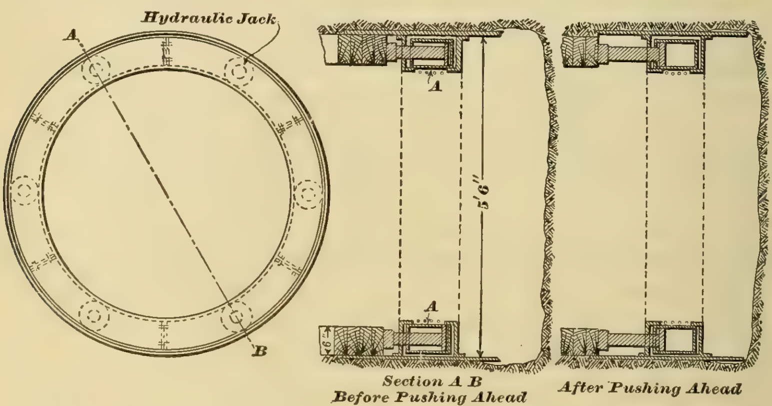


PLATE D.

SHIELD USED IN DRIVING MALDEN TUNNEL, MASS. PIPE LINE GAS CO.

placed by spiking to the previous work with 7-inch spikes, each ring breaking joints with the previous one. This construction, which was the same as that used in the tunnel proper, was found to be exceedingly rigid.

A few feet above the point where the tunnel was to be started, the tubular form was changed and the "goose neck" was started. This consisted in constantly lengthening that diameter of the shaft parallel to the axis of the tunnel, on the side from which it was to start, until room enough was obtained to turn a 54-inch pipe, 8 feet long, into the tunnel by a method similar to that shown in Plate B, Fig. 5. In this goose neck the sides were necessarily flat, but, being surrounded by stiff clay at this shaft, they showed no sign of weakness. At the Charlestown tunnel, however, the material was sandy and the side came in.

The shaft was driven 6 feet below what was to be the bottom of the tunnel, and 4 feet of concrete were put in as a foundation of the pipe that was to make the leg of the siphon (see Plate C).

The shaft on the Boston side was then sunk in the same way, and the tunnel started from that end.

In driving the tunnel a shield was used similar to the Greathead design, as shown in Plate D. The excavation was carried about two feet ahead of the shield in good digging, and the latter was pressed forward by the hydraulic jacks *a a* bearing directly against the lagging. This served a double purpose, pushing the shield forward and closing up the joints in the lagging, although, as the lumber was thoroughly dry when placed, it was found that the swelling of the wood made very tight work. The lagging was given a wash of cement after it was placed, and such leaks as showed were caulked with wooden wedges and yarn, and by feeding dry cement into the holes, the escaping air under pressure carrying the cement with it. (See Plate G.)

PLATE G.

North of the draw the tunnel ran beneath an ice guard, as shown on the general plan, Plate C, and the bottom of the piles had to be cut off in the heading. This occasioned no great hard-

ships, while the driving was in clay, but about three-quarters of the way across the river a streak of silt and sand was struck, which, being only 7 feet thick between the top of the tunnel and the bottom of the river, followed the piles into the heading and stopped the work.

Poling planks were driven ahead, similar to those shown in Fig. 6, Plate B, and cut so that the ends could be worked back on the cutting edge of the shield. Gunny sacks, filled with horse manure, sawdust, etc., were thrust into the cavities, and, as soon as the holes were plugged, they were quickly plastered with clay. The material ahead was then excavated and the shield pushed forward. The surrounding material was so soft and unstable that the lateral movement of the shield was scarcely controllable, the whole structure moving toward the side that caved in.

As a whole, however, after the soft material was passed and the transit line extended, the headings met within 0.42 inch. The tunnel was allowed to fill with water and to remain filled for a few days, to give the woodwork a chance to swell and to permit the silt to pack about the lagging.

To a great extent this closed the remaining leaks, so that a No. 5 3-inch pulsometer easily kept the water down after the air pressure was removed. After pumping the tunnel out, a cross-section was taken, and this, compared with one taken before, showed that the tunnel had flattened about ½ inch, thus proving that the lagging would not be permanent of itself.

In giving the line of the tunnel the distance between the shafts was triangulated and the direction transferred to the tunnel by means of two wires which passed through holes tapped in the air lock. This gave a base line about 4 feet long, which was produced into the heading by means of nails in the roof of the tunnel.

In this tunnel it was decided to lay pipe 54 inches in diameter, 8 feet long, with turned and bored joints, as shown in Plates E and F. The pipes were lowered in the shaft on the Boston side of the tunnel, turned on a pair of skids in the goose neck, the same as shown in Plate B, Fig. 5, and drawn through by an engine at the other shaft. A piece of timber was fastened to the tunnel, and the joints were forced home by a hydraulic jack which rested against it.

The joints were first smeared with sal-ammoniac, but it was found impossible to get them tight, as the turning was more or less irregular, and what sal-ammoniac was not washed off by the

water, refused to rust as it did on top. Instead of rust, a soft black coating formed on the metal, presumably due to the sulphuretted hydrogen which was present, and when this was wiped off the metal was left clean and smooth.

The leaky joints were caulked with copper wire, dry shingles, jute, cold lead and anything that best suited the particular leak, and the joints were filled flush with Roman Orchard cement. (Plate F.)

Between the pipe and the lagging was a space varying from nothing, where the lagging was cut out to improve the alignment, to 6 inches at a point diametrically opposite. This space it was proposed to fill with grout under pressure.

An expert with "experience" submitted a bid for doing this by forcing a mixture of lime and cement into the cavity. This was

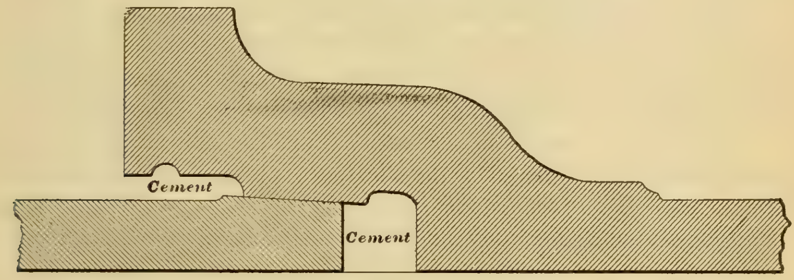


PLATE F.

TAPER JOINTED PIPE USED IN MALDEN TUNNEL, MASS. PIPE LINE GAS CO.

SCALE 1 : 4.

guaranteed to do the work, the lime being "greasy" and acting as a carrier for the cement. Meanwhile the engineers made a series of experiments as to the action of different cements and mixtures under conditions similar to those on the work. In each case grout was made, and poured into a pan containing salt water. All the cements to which lime had been added remained like so much mud; some of the cements with high records caked like dirt, while some of the cheaper low-grade cements took a quick initial set, which, of course, was what was wanted in this case. It was found that one brand of cement, into which steam was turned, became soft and slippery like paste and set very quickly. A jet of steam, acting on the principal of an injector, was accordingly used, the grout being mixed in a trough at the top of the shaft and carried down by 1½-inch pipes. (See Plate C.)

In laying the 54-inch pipes, bulkheads had been built between the pipe and the lagging every 25 feet or more. Each length of this pipe had a hole for a ¾-inch pipe tapped in its top, and into these holes the grouting pipes were successively introduced, the progress of the grouting being watched through the holes in the succeeding pipes, and these holes being plugged when the grout began to appear.

The steam jet was in the shaft, and as the reach from it to the introducing hole became greater and the time of changing forward became longer, the injector became plugged with cement and was finally abandoned, the pressure due to the height of the mixing trough being used and the pipe washed out with clean water after each succeeding run. When the distance became too great to get the desired pressure by this method, the grout was mixed in the tunnel and injected by means of a force pump.

From time to time the plugs were withdrawn from the top of the tunnel, and the grout cut through with a drill to determine its set and fill. The best results were obtained when the steam jet was used, the cement seeming to have swollen in setting.

Where the cavity was not entirely filled, the force pump was used to finish the work. In the shafts the pipes were concreted as fast as placed, the steel casing being left in.

In driving the tunnel the water was taken care of by two 4-inch pulsometers, and by two steam ejectors rigged tandem; that is, one at the bottom of the shaft and one halfway up.

On the completion of the tunnel the water of condensation and leakage amounted to 4½ barrels per day.

The tunnel was finished December 1, 1899, and gas was turned on about December 3. The drippage decreases to 2½ barrels a day in summer and increases to 19½ barrels a day in winter.

The Charlestown Tunnel was commenced as soon as the air lock could be spared from the Malden Tunnel. The dimensions and form of this tunnel are shown in Plate H.

The shafts were sunk in midstream from temporary platforms, and did not differ materially from those of the Malden Tunnel.

For convenience in handling the water in working from both shafts at once, the summit was placed between the shafts. This tunnel was driven without a shield, under an air pressure of 28 pounds, the clay being stiff enough to maintain the heading except in one part where gravel was encountered in the roof. Here poling boards, horse manure, etc., were used, as in the Malden Tunnel, except that the poling planks were worked back on the

lagging when cut off, instead of the shield as in that tunnel. (See Plate B, Fig. 6.)

The goose neck was turned in less favorable material in this tunnel, and on removing the bracing the flat side broke in. After ineffectual attempts to patch it, a concrete lining was placed, as thick as would allow the introduction and turning of the pipe. These were common bell and spigot pipe, 12 feet long, and were made up with cement joints.

The pipe was placed in the shaft on the Boston side first, and the concrete was brought up to the top of the steel caisson. The tunnel pipe was then started at that shaft and laid toward the Charlestown side.

A 3-inch pipe, provided with open tees, was suspended in the roof of the tunnel, and each length of 42-inch pipe was concreted as it was placed. The concrete was mixed over the shaft and dropped through a chute to a car that ran inside the pipe already laid, and was then dumped, remixed and rammed by men standing alongside of the pipe. (See Plate I.) Around the joints the concrete was made stronger, and greater care was used to make it impervious to water.

When the pipes were all laid and concreted, the 3-inch pipe in the roof was flushed with grout.

The shafts were protected by circular fenders, and also by outer channel fenders as shown by Plate H.

This tunnel was completed about January 1, 1900. It is the best one of the three, the only objection being the necessity of pumping two drips.

In the River Street Tunnel, Plates J and K, the Brighton shaft was sunk 90 feet, and the Cambridge shaft 60 feet. It was commenced by sinking the Cambridge shaft without the steel caisson and running the tunnel in 80 feet without compressed air. At that point the clay changed to a vein of sand, and the heading came in, filling the tunnel for 40 feet and destroying the cross-section.

The Brighton shaft was then sunk to a depth of 90 feet before enough clay was found to turn a goose neck. The old shield could not be used, because it was not large enough, and on account of the scarcity of steel it would have taken too long to procure a new one. As matters turned out it would have been better to wait for a shield, but the borings seemed propitious and a heading was started.

The enormous head made 36 pounds air pressure necessary and also greatly increased the leakage, as much as 1,000,000 gallons daily being pumped by three Knowles 5-inch pumps.

After going a short way, the roof material changed to sand and continued so to the completion of the tunnel. "Cave-ins" and "breakdowns" were of everyday occurrence, and every incentive was used to keep the men at work.

Negroes were worked in one heading and white men in the other, pitted against each other as to courage and record; extra time was given and shifts shortened, but under the heavy pressure, with the temperature at 105° and the slow laborious methods necessary in the uncertain heading, progress was very slow, and it was only the indomitable courage of the contractor that carried the work to a successful completion.

The general method of procedure was as shown in Plate B, Fig. 5. Poling planks were driven ahead, a couple of feet of the sand was excavated, the surface was smeared with clay to hold the air and a bulkhead was thrown across. The clay bottom was then excavated, the lagging brought forward and a new start made in the sand. Progress was from one to three feet a shift in each heading.

The results in alignment were such that it was necessary to make two offsets of 2 feet each, to keep the transit line in the tunnel. Nevertheless the closing error was less than 0.05 foot.

The lagging was lathed and plastered with cement, and about 6 inches of concrete was placed in the bottom while the air pressure was still on. The air lock was then removed, and six 12-foot lengths of 48-inch pipe, with the drip, were lowered in the Cambridge shaft, the lock was replaced, and these were hauled through to the Brighton shaft (see Plate B, Fig. 5), where two lengths were supported in the shaft while the drip was set and concreted.

These two pipes were then set and concreted, and a 6-inch drain pipe was laid in the concrete connecting the tunnel with that part of the shaft above the pipe. The five other lengths were laid from the drip in the tunnel, and the 6-inch drain pipe was continued beneath them. Owing to the rapid rise in the tunnel, shown in Plate K, this had the effect of materially reducing the head, and when six more pipes were laid in the tunnel in the same way, an attempt was made to proceed without the air pressure.

There was too much leakage, however, for the three pumps in the Brighton shaft, and there was no room for more pumps. Moreover the pumps or their connections were continually breaking down and it was decided to lay the pipe under pressure.

The general methods were about the same as those used in the Charlestown Tunnel, except the plastering of the lagging, the

laying of the 6-inch drain and the handling of the concrete. The concrete was mixed on top, lowered through the air lock in canvas bags, twelve or sixteen at a trip, and wheeled to the point of laying in three or four barrows, four bags filling one barrow. As each man dumped his load, he wheeled his empty barrow into the pipe to make room for the man behind him.

The proportions of the concrete were: 1 cement, 2½ sand, 5 broken stone. In two hours this set sufficiently to permit walking over.

As a rule three 8-hour shifts of 9 men each were employed in driving the tunnel, and progress was about three feet each shift.

In laying and concreting the pipe, there were two 11-hour shifts of from 11 to 13 men, averaging one pipe each shift. There were eight batches of concrete to each length of pipe. The men received 23 cents an hour when working under pressure.

The plant included 3 locomotive boilers, 2 upright boilers, one 5-drill and one 4-drill unjacketed compressor, and one 14-inch and one 10-inch jacketed compressor, one 6-inch and three 5-inch steam pumps at 75 pounds and 110 pounds steam pressure, respectively, three 3-inch pulsometers and two 4-inch ejectors.

As in the other tunnels, all joints on the inside of the pipe were filled flush with cement.

The cost of the Malden Tunnel was $35.34 per lineal foot for driving the tunnel, $15.50 per lineal foot for the pipe and $4.80 per lineal foot for laying the pipe and grouting, or $55.64 per lineal foot complete.

On the Charlestown tunnel the cost was as follows: Driving and fenders, $87.45 per foot; pipe, $4.35 per foot; laying, $9.60 per foot; total cost, $101.40 per foot.

The quantities were as follows: Concrete, 420 cubic yards; 42-inch pipe, 85 tons; cement, 260 barrels, at $2.35 to $2.75; sand, 200 tons, at 70 cents; stone, 600 tons, at $1.

At River Street Tunnel the cost was as follows: Driving, $48.84 per foot; laying, $45.45 per foot; pipe, $5.36 per foot; total cost, $99.65 per foot.

The quantities were: Concrete, 560 yards; stone, 1303 tons, at $1.10; sand, 97 loads, at $1.60; 48-inch pipe, 169 tons; cement, 859 barrels, at $2.35 to $2.75.

Cost of labor on concrete in tunnel about $5 per cubic yard. Cost complete of concrete in tunnel about $9 per cubic yard.

While driving the River Street Tunnel, owing to its uncertain termination, it became necessary to lay a temporary pipe on the River Street Bridge and to sink a small siphon at the draw. A

20-inch pipe was, therefore, laid on the bridge, and a siphon, made from 12-inch threaded wrought iron pipe, was sunk through the bridge by cutting holes 4 feet square for the legs of the siphon, lowering them through and connecting up with the extension piece before sinking them into the water.

The whole work was done and gas was flowing inside of six days from ordering the stock. The little pipe was eminently successful, there being only a head of 1 inch water pressure lost in passing the siphon, and the pipe was easily removed when the tunnel was completed.

The amount of gas passed at that time was 2,500,000 feet per diem, and the pressure was 7 inches to 10 inches water column.

The choice between driving a tunnel and sinking a siphon is naturally governed by the location. Where the requirements of depth and width are great and the obstruction to navigation while sinking the siphon is serious, especially in the case of a double draw, the tunnel is cheapest in any ground. The same may be true of a single draw in good ground. Where the pipe, for any cause, cannot be supported by the bridge, and the approaches are exposed to ice and heavy shipping (a condition requiring strong fenders) and where the earth is propitious, it may be cheaper to tunnel the entire river, as was done at Malden Bridge.

Where the channel may be obstructed by temporary piling, and where the requirements as to preserving the channel are not burdensome, a siphon is undoubtedly the cheapest, as in the crossing of Island End River, now under way. It is needless to say that a tunnel is *always the best.*

In these tunnels it has been demonstrated that in good clay, and in good clay only, a tunnel can be advantageously driven without a shield under compressed air; that the segmental lagging, as used by Mr. Haskin, is an easy, economical and stable method; that breaks, even in bad ground, are neither necessarily dangerous nor prohibitively difficult; that a large tunnel, with concrete between the pipe and the lagging, although more costly than a smaller tunnel grouted, makes much tighter work; that turned and bored joints are a delusion and a snare; that it pays to point up the joints on the inside of the pipe with cement; that cement joints give the best results, and are the cheapest and most convenient; that lathing and plastering the lagging with cement, while under compressed air, is an advantage.

Mr. G. H. Finn is the general manager and Mr. L. J. Hirt was the chief engineer of the Massachusetts Pipe Line Company. W. E. Silsbee had immediate charge of the Malden and Charles-

town Tunnels, while E. C. Hayden had immediate charge of the River Street Tunnel.

DISCUSSION.

Mr. Howard A. Carson.—I have been very much interested indeed in the paper which has been read to-night. It recalls the experiences of myself and those associated with me some years ago when I was engineer of the Metropolitan Sewerage System. All that is ancient history now, but I refer to it at the request of the President and Secretary. The author has alluded to the tunnel crossing near the Malden Bridge beside the new gas tunnel. On that there were some interesting experiences. Mr. Haskin was connected with that. During one serious blow-out the men were compelled to leave the tunnel, and the whole tunnel was filled with water in about an hour. This tunnel was at one point so close to the bed of the stream that, among other experiences, was the finding of a human skeleton in the mud at the top of the tunnel.

The engineer of to-day, tunneling under deep beds of water, is very much more fortunately placed than those of a generation ago, before compressed air for tunneling was brought into use. You have all read of the various attempts which were made to build a tunnel under the Thames early in the last century, of the very slow progress and how several of these attempts were given up. A long time was used, seventeen years, in making the first successful Thames tunnel. The engineer now, if he has occasion to go under a stream of moderate depth, can make use of either of several processes.

In the work on the Metropolitan Sewerage System there were six passages built under tidal estuaries, "siphons," we called them; one on the outer end of Deer Island, about eighteen hundred feet into the sea; one under Belle Isle Inlet; one under Shirley Gut; one under the Mystic River, at the point spoken of by the author this evening; one under the Malden River, and one under Chelsea Creek. In two of these cases, Belle Isle Inlet and the Malden River, the cofferdam process was used. At Malden River, the cofferdam was quite successful; that is, there were no serious mishaps of any kind; the trench was flooded once, but there was no serious trouble. At Belle Isle Inlet, however, where the cofferdam was also tried, the process, as carried on, was very unsatisfactory, the trench being flooded many times. It was finally necessary to make use of somewhat novel processes for finishing up the work.

As most of you remember, a novel method was used at the outer end of Deer Island extending into the sea, and in crossing

Shirley Gut, in sinking and connecting large pipes made of brick and concrete. In these two cases, so far as rapidity and economy of the work was concerned, the results were superior to any of the other methods tried. At Shirley Gut the pipes were from 48 to 65 feet long and over 8 feet external diameter. They were made on the shore above high tide and moved down to low tide by means of blocks and rollers, as in moving houses. The ends were stopped up, so as to make the pipes water-tight. They were finally floated to their proper position, and methods taken to place them accurately on the bottom, join them together and afterwards remove the bulkheads.

Some allusion has been made to the East Boston Tunnel. I hope most of the members will visit this tunnel within a few days. The work has now progressed, by the shield, something like 240 feet. The work is temporarily arrested, to put in the air locks. Before the compressed air is used will be an excellent time for the members to view the whole situation. As you will learn all about it then, I will say now but a word for those who cannot go.

The general method employed there is almost precisely the same as that which was used on the subway tunnel on Tremont Street. There are two drifts about 8 feet square, made and timbered by an ordinary tunneling process. These drifts are about 30 feet apart horizontally, outside to outside. In each of these drifts one of the side walls of the tunnel is built. The shield of the tunnel is later moved along, running on top of and resting on these side walls. The arch of the tunnel is built under the tail end of the shield, and, of course, joins with the side walls just mentioned. The invert is put in later. The hydraulic jacks, which push the shield along, react against cast-iron rods imbedded in the masonry of the arch, the same as on Tremont Street.

The main difference between the Tremont Street tunnel and that of East Boston is that, in the latter case, the arch is of concrete, while in the Tremont Street tunnel it was of brick. The cross-section in East Boston is considerably taller. The arch, instead of being very flat, is a semicircle.

Mr. C. M. Saville.—The Metropolitan Water Board has just completed a small tunnel between Chelsea and Charlestown. The contractor for the gas tunnels also did the work for the water board, and many of the men were employed on all of the work. The methods employed on our work were substantially the same as the author has so interestingly described. Two water shafts were sunk, one on each side of the channel and about

140 feet apart. These shafts were about 65 feet deep, and connected at their bottoms by a drift under the channel. The net inside diameter of each shaft and drift was 6 feet, and they were lined throughout with a foot of brick masonry laid in Portland cement mortar. The same shield was used as has been described by the author, but it was remodeled to work the heading, which had a gross diameter of about 9 feet. The material encountered was mostly sand containing considerable water. Much difficulty was encountered in keeping the shield on line and to grade, and, after the drift was about three-fourths completed, the shield was removed and the remainder of the work was done with poling boards. After the tunnel was completed, a 24-inch ordinary cast-iron water pipe was laid in it by the maintenance department, and this pipe is now in use.

During the progress of the work, an article appeared in one of the Boston papers purporting to be a description of the methods employed, and among other interesting points brought out was the statement that for every pound of material excavated a pound of air was pumped in to take its place.

Mr. Robert A. Shailer.—I do not know that I have anything to say except that I have enjoyed listening to Mr. Cummings's paper on subaqueous tunnels.

I am sure that an ordinary mud digger like myself cannot be expected to have much to say of interest to this society, which certainly contains among its members very prominent engineers, probably the best engineers in the country.

In the paper just read considerable stress was laid upon the use of compressed air for the purpose of keeping out water, and the thought occurred to me that possibly you are not all familiar with the use of compressed air for the purpose of keeping clay from flowing or swelling, as it is usually termed.

We have been working for a number of years at Cleveland, Ohio, constructing a tunnel 9 feet inside diameter, with 12-inch brick walls and 26,000 feet long. The 22,000 feet already completed have been constructed through a very soft, swelling clay; in fact, a material which it would be almost impossible to handle without compressed air. It contains no water to speak of, and if any of you were to go into the tunnel under our usual pressure of 28 to 30 pounds of air, the clay would seem practically dry and quite stiff and hard, and it would be difficult to realize what it would be without the air pressure.

In sinking shaft No. 2, which is composed of cast-iron cylinders extending from above the surface of Lake Erie down nearly

to the top of the arch, which is at about grade minus 94, and then underpinned with brick, we had occasion to take the air pressure off, and where square openings like windows were left for the purpose of breaking out into the drifts, I have seen clay flow in through said openings and drop off in large chunks, while with the air pressure the clay appeared still and stable. Last fall, when one of the air locks in the tunnel got to leaking, so that the pressure was almost entirely lost, the clay flowed into the completed tunnel so as to nearly fill it up solid for some twenty feet.

Mr. Carson has just spoken of our being about to put on the air pressure in the East Boston Tunnel. We anticipate no trouble or danger from water in carrying on this work, but we do expect to have swelling clay, and it is to hold the clay that we are installing the pneumatic plant.

There is another use of air pressure in which we have had some experience, and that is for the dilution of explosive or marsh gas, as it comes into the tunnel.

At Cleveland the whole ground is saturated with this gas, and chemical analysis shows that even with great care we have from ¾ to 1½ per cent. of this gas at all times in the air which the men breathe. If our pressure goes down, the percentage of gas becomes greater, so that we are reasonably sure that the use of compressed air tends to keep the gas out. The mixture of 5 or 6 per cent. of gas is exceedingly explosive, while a mixture of 9 to 10 per cent. is not. This may seem paradoxical, but it is true. What I have always feared is that, as the gas must flow into the tunnel practically pure, there must be, somewhere between that and its dilution down to 1½ per cent., a point at which the mixture is dangerous. We therefore watch our electric wire connections, and take all the precaution we can and carry our inlet pipe straight up to the heading, so as to dilute the gas there.

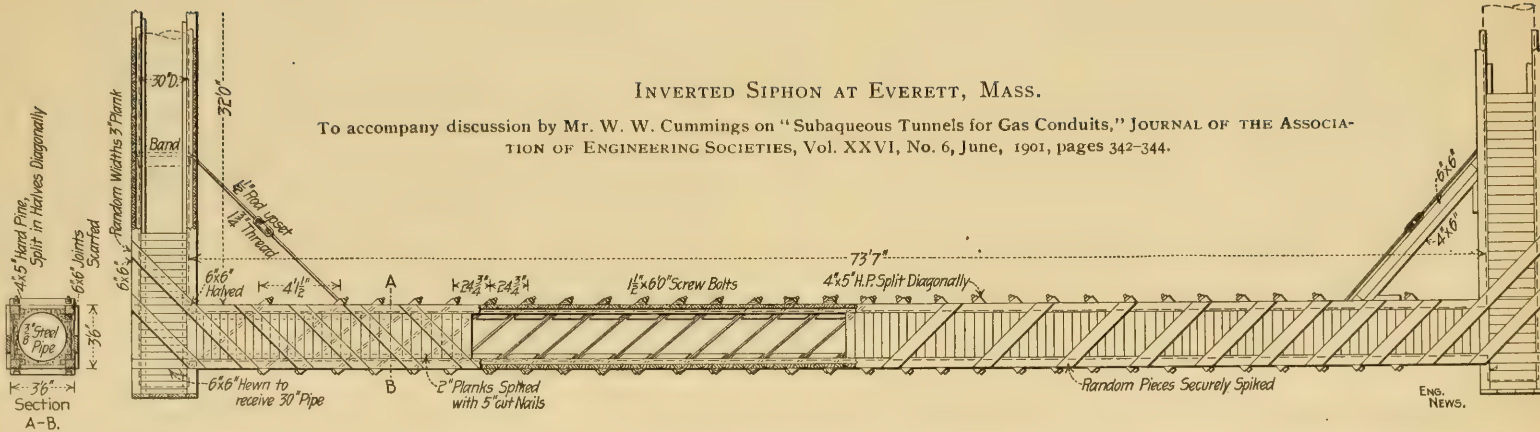
Compressed air has been used to retard the flow of water into tunnels where the head was so great that sufficient pressure could not be maintained to keep the water out entirely. Under these conditions the work of necessity must be carried on very slowly and at great expense.

Mr. W. W. Cummings (by letter).—An inverted siphon possibly a little out of the ordinary line was placed in Everett, Mass., May 21. Its characteristics were its economy and its rigidity, notwithstanding its rather unusual length.

The Harbor Commissioners required that a clear waterway 60 feet wide and 18 feet below mean low water should be preserved.

Inverted Siphon at Everett, Mass.

To accompany discussion by Mr. W. W. Cummings on "Subaqueous Tunnels for Gas Conduits," Journal of the Association of Engineering Societies, Vol. XXVI, No. 6, June, 1901, pages 342–344.



The river bottom at this point is but 4 feet below mean low water, the channel as yet not having been dredged.

As shown by the drawings, the siphon was made up of a 30-inch riveted steel pipe $\frac{3}{8}$ inch thick, the legs being about 32 feet long and the extension piece about 74 feet long on centers; and an inclosing box 3 feet 6 inches square, made up of 6 x 6-inch spruce corner posts, with 3 x 4-inch sticks spiked to them for the nailing of the 2-inch cover planks.

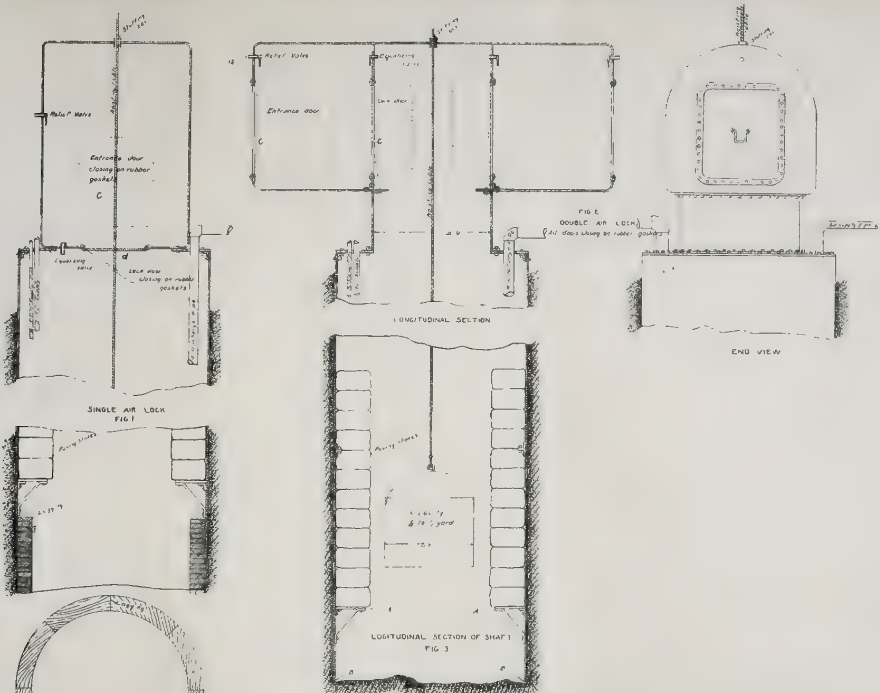
It was designed to make the siphon as light as possible. Therefore the steel pipe was figured to be self-supporting when hung by the two legs, and only sufficient concrete was added to sink the pipe and its inclosing box. The sides of this box formed two trusses, calculated to support the box and the contained concrete when hung by the legs of the siphon, or to have sufficient excess of strength, when submerged and supported at its center, to make up the deficiency in the steel pipe when supported at that point. Particular care to secure an even bottom in the dredging was therefore unnecessary. The angles of the siphon were reinforced by $1\frac{1}{2}$-inch tie-rods and two 6 x 6-inch struts bearing on pieces of angle iron.

The weight of the siphon complete was about 60 tons, or 900 pounds per lineal foot; and 9 tons, or 125 pounds per lineal foot, when submerged.

The pipe and the extension piece of the box were constructed on shore. These were then placed on temporary piling in the channel by means of a lighter, and concrete, composed of one part Star cement to one part unscreened fine gravel, was added after smearing the joints of the steel pipe with neat cement mortar. The legs of the box were then carried up, the concrete being added as the work progressed, and the whole was allowed to set for six days. Particular care was taken to make the concrete impervious to water. In placing the siphon, three lighters were used, one large one on one leg and two smaller ones on the other. When lifted free from the blocking, the deflection at the center was about $1\frac{1}{2}$ inches. The lowering consumed about two hours. When in place, the pipe was under a maximum head of 26 feet, and remained twenty-four hours without showing any leaks. It was then filled with water and allowed to settle to its bearing.

The whole siphon, with the exception of the 6 x 6-inch and 3 x 4-inch spruce timber, was made from the scrap pile at a cost of $592.62. The material new would have cost about $685, making a total new of about $9 per lineal foot. The dredging cost $1800, and the placing about $600.

Without searching the records, it is believed that this is the longest and largest siphon in the vicinity, that of the Boston Water Department at the Warren Bridge being 24 inches in diameter and 55 feet long, and that of the Metropolitan Water Board at Saugus River being 20 inches in diameter and 48 feet 8 inches long. This latter one cost $23 per lineal foot. It might be added that the siphon was subject to extremely rough usage while being lowered, but it was perfectly rigid and the concrete showed no signs of cracking.



SINGLE AIR LOCK
FIG 1

FIG 2
DOUBLE AIR LOCK

LONGITUDINAL SECTION

END VIEW

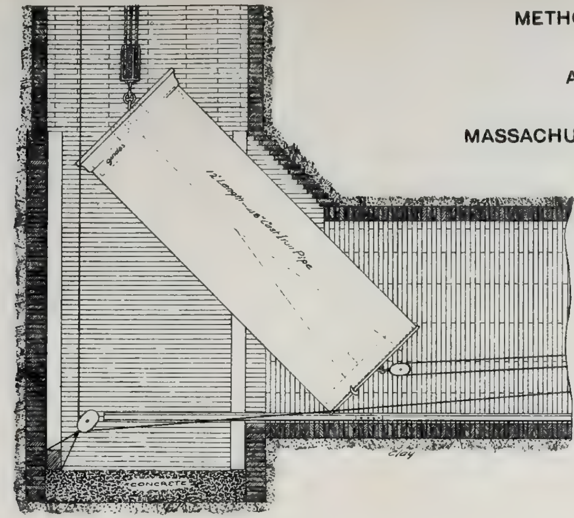
LOGITUDINAL SECTION OF SHAFT
FIG 3

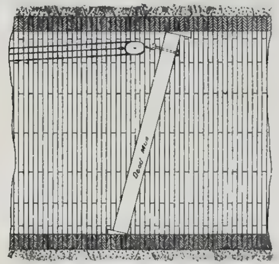
FIG 4
SECTION SHOWING LAGGING

STEEL CASING AND AIR CHAMBER
USED IN MALDEN TUNNEL
MASSACHUSETTS PIPE LINE GAS CO.
SCALE 1:48

METHOD OF CONSTRUCTION IN THE ALLLSTON TUNNEL OF THE MASSACHUSETTS PIPE LINE GAS CO.

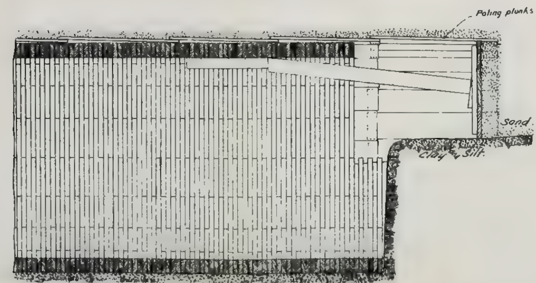
SCALE 1:48

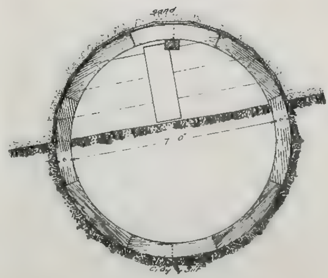




GOOSENECK

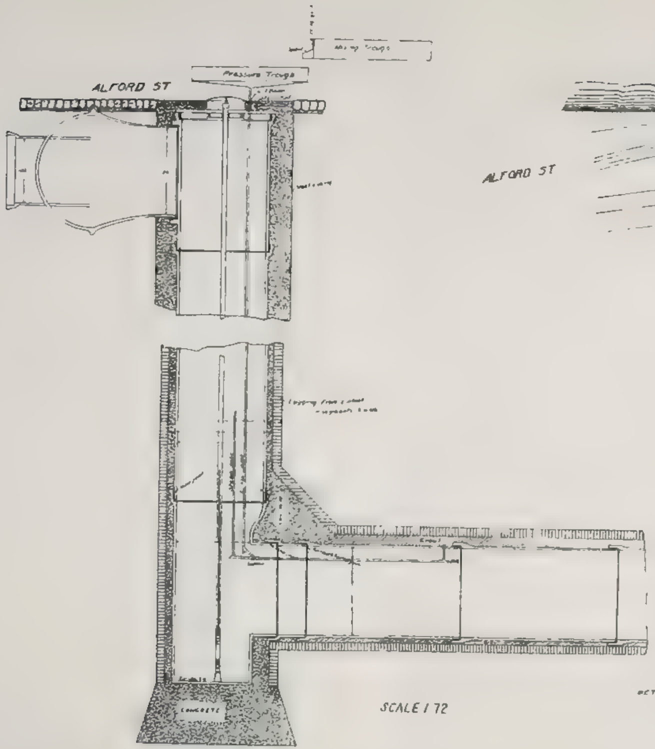
FIG. 5

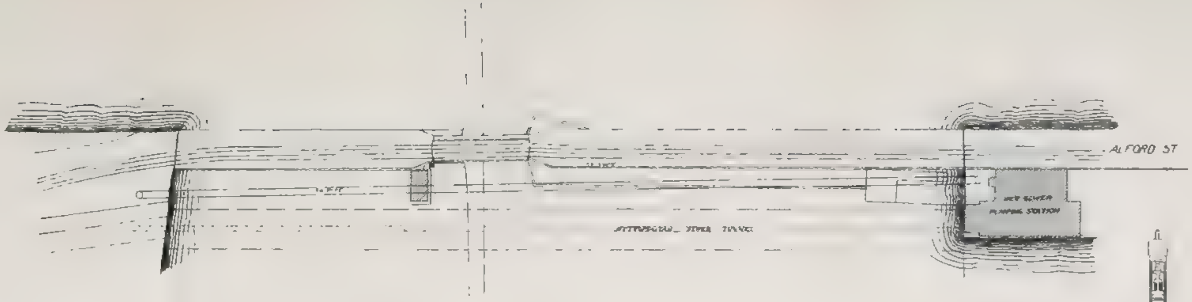


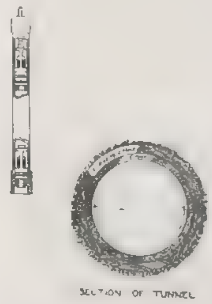


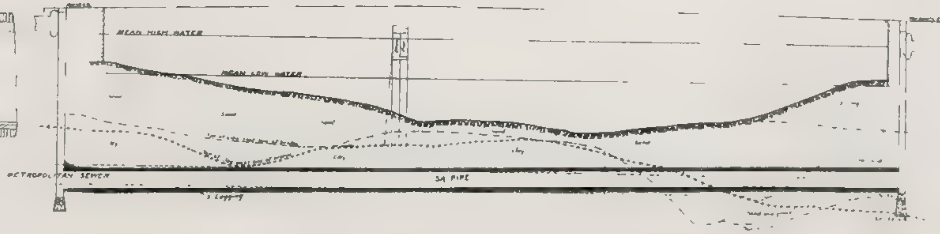
HEADING

FIG 6







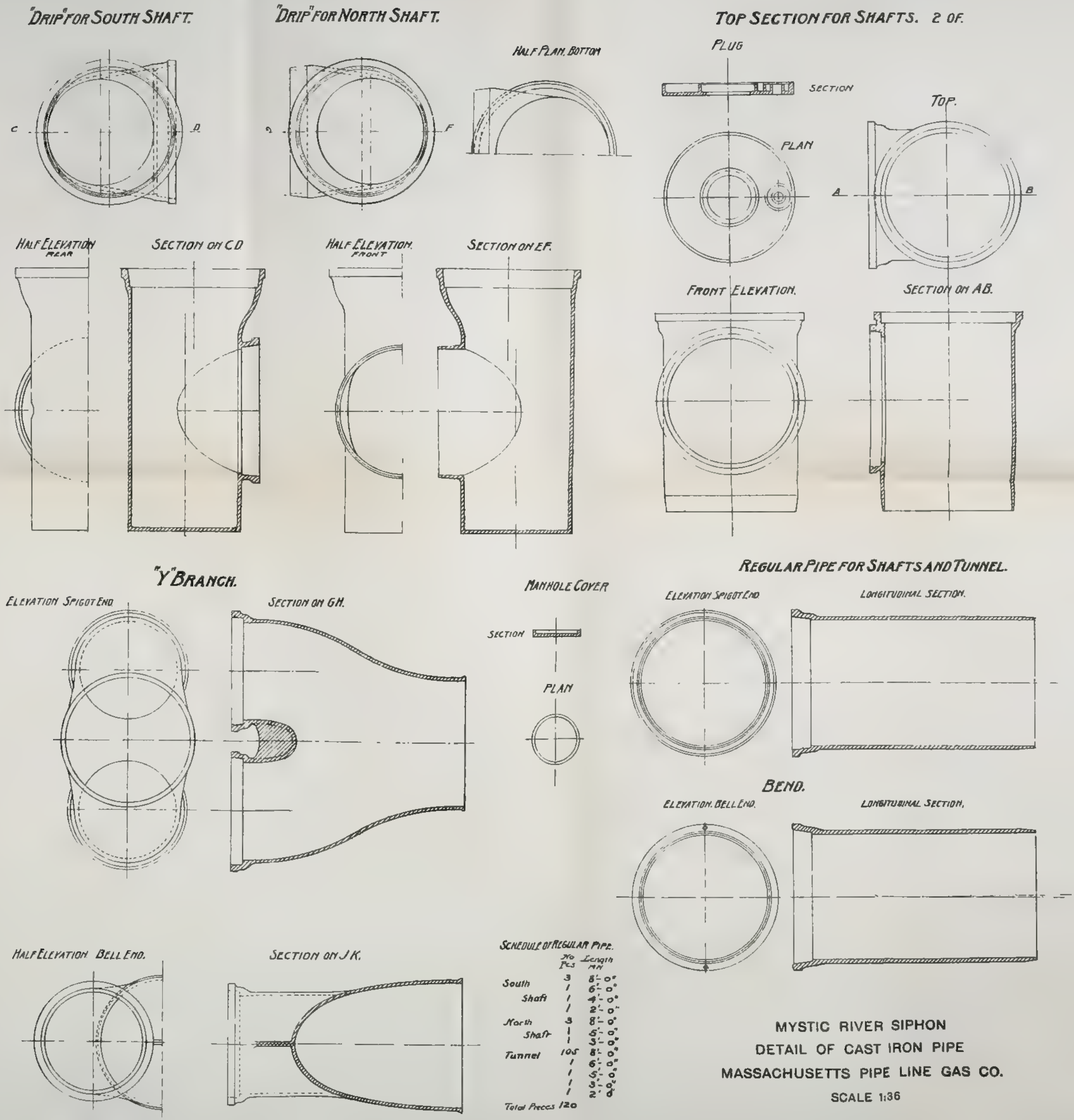


PLAN AND PROFILE
SHOWING LOCATION OF MAINS
OF THE
MASSACHUSETTS PIPE LINE GAS CO.
IN ALFORD ST.
CHARLESTOWN DISTRICT, BOSTON

SCALES { HORIZONTAL 1:1080
VERTICAL 1:360

E LINE GAS CO.

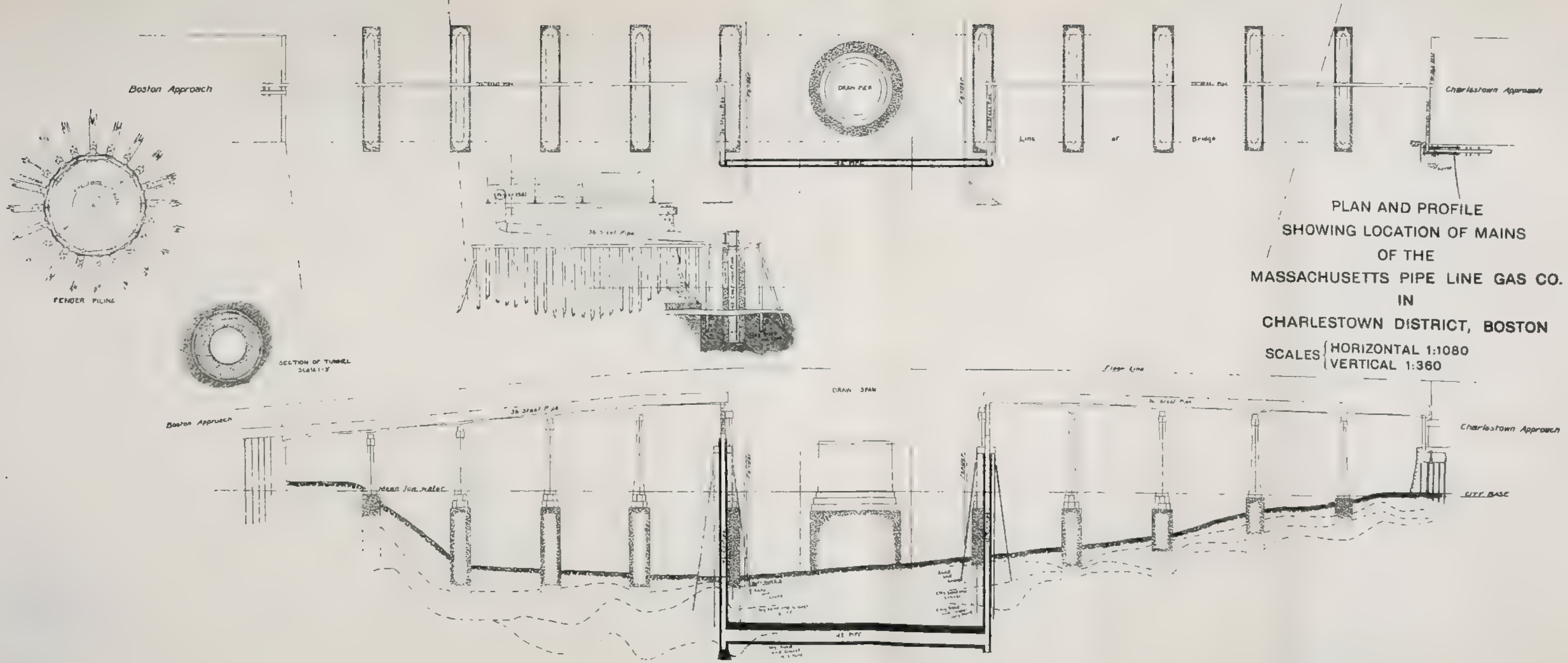
:36



SCHEDULE OF REGULAR PIPE.

	No Pcs	Length
South	3	8'-0"
	1	6'-0"
Shaft	1	4'-0"
	1	2'-0"
North	3	8'-0"
Shaft	1	5'-0"
	1	3'-0"
Tunnel	105	8'-0"
	1	6'-0"
	1	5'-0"
	1	3'-0"
	1	2'-0"
Total Pieces	120	

MYSTIC RIVER SIPHON
DETAIL OF CAST IRON PIPE
MASSACHUSETTS PIPE LINE GAS CO.
SCALE 1:36

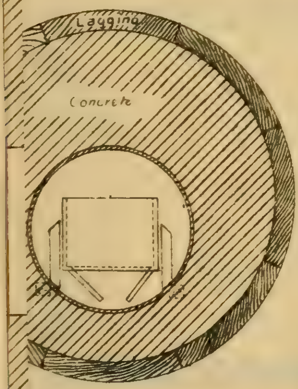


PLAN AND PROFILE
SHOWING LOCATION OF MAINS
OF THE
MASSACHUSETTS PIPE LINE GAS CO.
IN
CHARLESTOWN DISTRICT, BOSTON

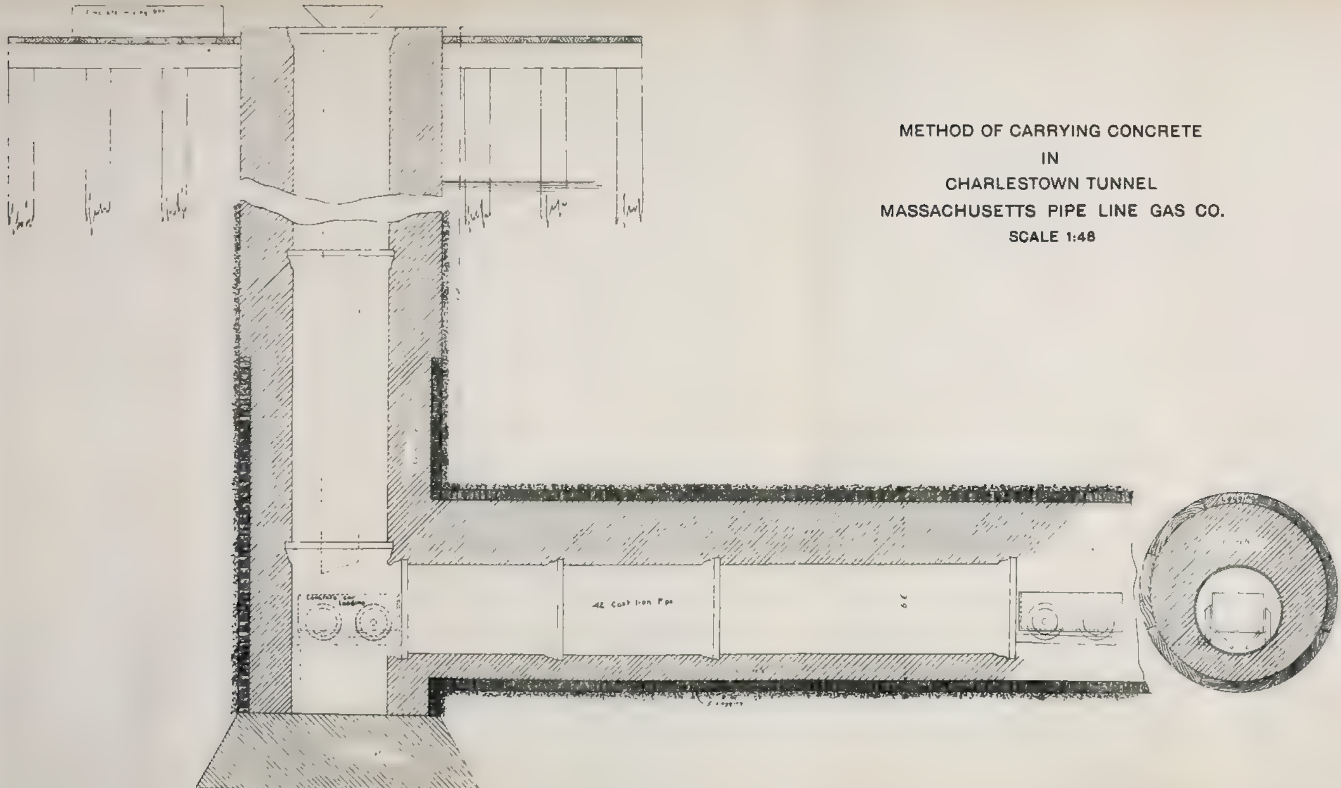
SCALES { HORIZONTAL 1:1080
VERTICAL 1:360

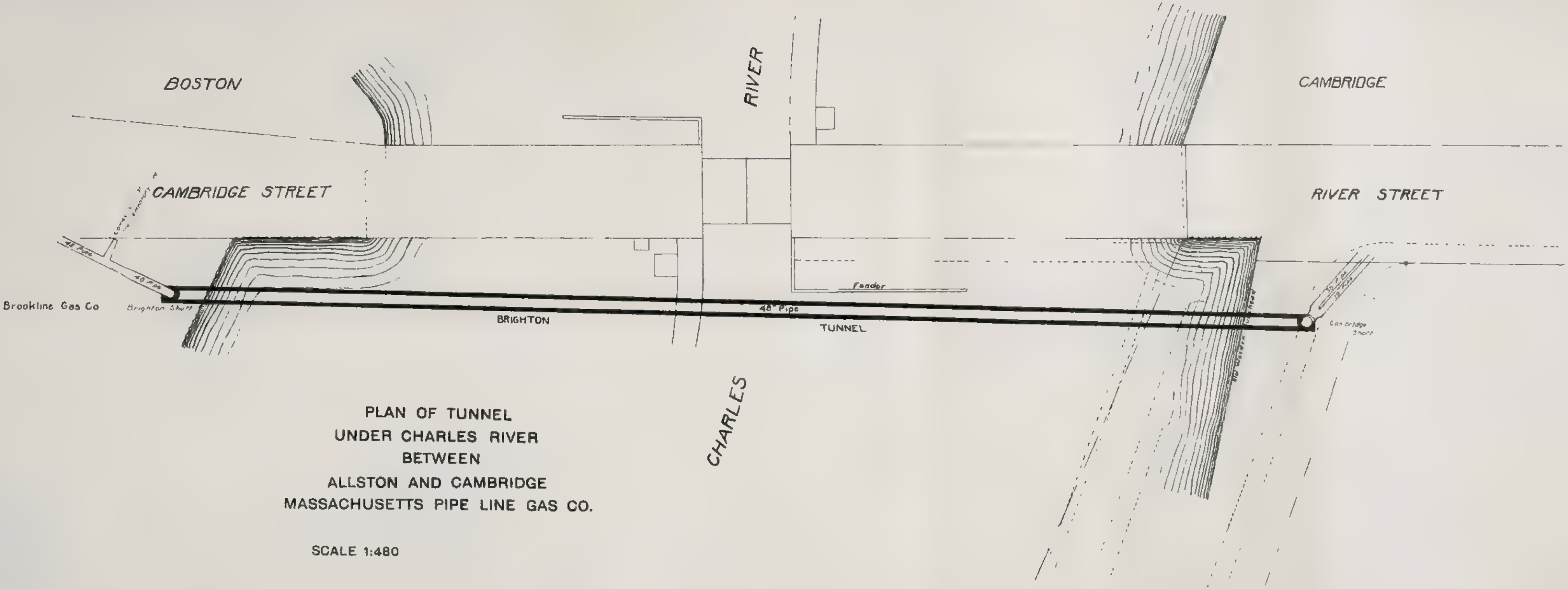
E

CO.



METHOD OF CARRYING CONCRETE
IN
CHARLESTOWN TUNNEL
MASSACHUSETTS PIPE LINE GAS CO.
SCALE 1:48



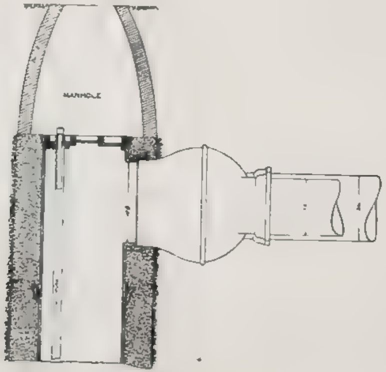


PLAN OF TUNNEL
UNDER CHARLES RIVER
BETWEEN
ALLSTON AND CAMBRIDGE
MASSACHUSETTS PIPE LINE GAS CO.

SCALE 1:480

SECTION OF TUNNEL

CONNECTION TO BRIGHTON SHAFT



CONNECTION TO CAMBRIDGE SHAFT

PROFILE OF TUNNEL
UNDER CHARLES RIVER
BETWEEN
ALLSTON AND CAMBRIDGE
MASSACHUSETTS PIPE LINE GAS CO.

SCALES { HORIZONTAL 1:720
VERTICAL 1:180 }

THE INCREASING ELEVATION OF FLOODS IN THE LOWER MISSISSIPPI RIVER.

By Linus W. Brown, Member Louisiana Engineering Society.

[Read before the Society, March 11, 1901.*]

My acquaintance with the Mississippi River began in 1880, twenty-one years ago, and for the past fifteen years I have been directly connected, officially and otherwise, with the levee work at this point, and I cannot fail to appreciate the material changes which have taken place during these two decades, in dimension of levees required to properly protect this section against inundation.

Twenty years ago the levees were of very small dimensions and very low in elevation as compared with those now existing. As I remember, the levees in the third district were but little larger than a well-banked potato row, and were located from 75 to 100 feet from the front street (North Peters), and the elevation of levees along the Commercial front was several feet lower than they exist to-day.

The serious and most important question presented is, what do the facts, as gleaned from the two decades just passed, teach us, and what conclusions are to be drawn? In my opinion, the facts, as presented, most conclusively demonstrate that to secure in the future the same protection against inundation as in the past and at the present time, there will be required a continual raising and enlarging of the levees, and the conclusions to be drawn are that in a very few decades (taking the past two decades as a criterion) the construction of levees to properly secure us against inundation will become a prodigious undertaking, both as an engineering feat and as a revenue consumer, owing to the very large proportions that will be required.

The question, what will be the height of levees for proper future protection against the inundation of the Mississippi Delta? demands immediate attention, and should be given the most careful thought and consideration. The maxim: "He only is free from danger who, even when safe, is on his guard," embodies the sentiment which should pervade every interest throughout the Mississippi Delta, and which should stimulate us to inaugurate at once a careful investigation and to apply such remedies or adopt

*Manuscript received May 20, 1901.—Secretary, Ass'n of Eng. Socs.

such methods as will measurably well assure us of a moderate maximum elevation of levees for future protection. It is not too soon to inaugurate the necessary measures for a thorough investigation and secure the co-operation of all interests, and invite the attention of, and secure the necessary assistance from, the Federal Government to meet the issues which are now most apparent of future consummation, unless thwarted.

What are the causes of the constant increase in elevation of floods in the Lower Mississippi, why are the maximum floods sporadic; seldom, if ever, occurring in yearly succession, why should the maximum floods increase in elevation when a corresponding increase of discharge is not, by investigation, apparent, and why did the normal flood of 1898, discharging very considerably less volume than the great flood of 1851 or of 1890, require greater flood elevation? The United States Government gaging of May 2, 1898, shows that the elevation of flood was 16.65 feet on gage, and the discharge 1,084,000 cubic feet per second, whereas on February 26, 1890, the flood elevation was 14.7 feet on gage, and the discharge 1,422,000 cubic feet per second, which shows that the flood of 1890 discharged 338,000 cubic feet per second (or 30 per cent.) more water, and at an elevation of 0.95 feet (or 0.6 of 1 per cent.) less than that of 1898. On March 17, 1851, the gaging as recorded shows a discharge of 1,153,000 cubic feet per second, with a flood elevation of 14.8 feet on gage.

When the causes are ascertained, what are the remedies to be applied or the methods to be adopted to maintain a comparatively uniform elevation of maximum floods?

These are the questions to be solved, and they should receive the immediate and earnest consideration of every interest throughout the Mississippi Valley. And I will predict that the proper solution of these important questions will keep every member of this society of engineers busy for some time to come. The matter is of such paramount importance that it should enlist the very best endeavors of each and every one of us, and we should not be satisfied until we have secured some measurable degree of success.

Before attempting to lay before you an outline of my views of the cause producing the conditions, or the remedy to apply, I would refer to the following statistics and facts to amplify and form base for the conclusions and suggestions I may present.

All elevations used in this paper will refer to the Carrollton gage of the Mississippi River Commission, zero of which is 20.91 feet above Cairo Datum or 0.35 feet below mean ocean level; and all velocities and discharges referred to are those contained in the

reports of the Mississippi River Commission. The distance from the Carrollton gage to mean ocean level in Gulf is, for the calculation of slopes, assumed at 120 miles. The reports of the Mississippi River Commission do not contain statistics as to elevations at the heads of passes or at Fort Jackson, excepting from 1891 to 1898 at the latter point. I also note the incompleteness of the reports as to elevations, discharges and velocity of the river at any point, in that they cover only a few days of the year and often do not cover the maximum conditions. The discussion of the subject at this time may require some deductions to be made, and any conclusions reached will be understood as being susceptible of such modification as more full and correct data may conclusively determine to be correct and proper.

I remember the newspaper reports of the flood of 1874, which flood overtopped the then existing levees, and later I became familiar with the effects of this great flood, which reached the then extraordinary maximum elevation of 15.7 feet on gage, or 15.35 feet above sea level, although the elevation of this flood was only 6 inches higher than that of 1828, forty-six years previous, and was not as high by 0.2 of a foot as the flood of 1862, as recorded in the Government records. The average slope of this flood of 1874 to sea level was 0.128 of a foot per mile, or about 1 foot in 8 miles. The records of velocity and discharge are not embraced in the Government reports, but assuming the gagings of March 14, 1891, when elevation of flood was 15.6, as a comparative estimate of the velocity and discharge for flood of 1874, we have 6.95 feet velocity and 1,202,000 cubic feet discharge per second.

The flood elevation of 1874 was not surpassed until 1890, when it reached an elevation of 16.1 and in 1892 of 17.35 and 1893 of 17.45, and the greatest of all floods occurred in 1897 when the maximum elevation was 19.17 feet or 3.47 feet higher than the extraordinary flood of 1874, twenty-three years previous.

The elevation of flood of 1897 at Carrollton was 18.82 feet above ocean level, and the average slope from Carrollton to ocean was 0.156 of a foot per mile or 1 foot in 6.3 miles, or 22 per cent. greater than the slope of 1874, and while the Government reports do not give the gaging as to velocity and discharge on the day when the greatest elevations were noted,—viz, May 13, they give, for May 18, a velocity of 7.3 feet and a discharge of 1,350,000 cubic feet per second, gage reading 18.7 feet, and this gaging is the greatest, both as to velocity and discharge, of any shown in the reports, which further shows that while the difference in

elevation of the flood of 1897 above the sea level was 22 per cent. more than that of 1874, twenty-three years previous, the discharge was only 12 per cent. greater.

The history of the great floods, as recorded, is as follows:

Dates.	Gage reading.	Height above sea level.	Slope per mile.	Velocity.	Discharge.
1828—April 1	15.20	14.85	0.123	5.90	1,099,000
1849—March 15	15.20	14.85	0.123	5.90	1,099,000
1851—March 27	15.40	15.05	0.125	5.99	1,118,000
1858—May 10	15.10	....	....	...	1,168,000
1859—May 4	15.60	15.25	0.127	6.00	1,156,000
1862	15.90	15.55	0.130	6.68	1,243,000
1874—April 16	15.70	15.35	0.128	6.75	1,175,000
1890—March 13	16.10	15.75	0.131	6.90	1,292,000
1892—June 10	17.35	17.00	0.141	5.87	1,079,000
1893—June 22	17.45	17.10	0.1425	5.82	1,113,000
1897—May 13	19.17	18.72	0.156	7.30	1,350,000
1898—April 25.........	15.90	15.55	0.130	5.73	1,024,000
1899—April 21.........	16.00	15.65	0.135	6.81	1,182,000

The velocity and discharge for the years 1851, 1890, 1892, 1893 and 1897 are the results of gaging on these dates as contained in the reports of the Mississippi River Commission, but those for the other years are not given in the reports, and the velocity and discharge for these years are interpolated from the records of other years when gage readings or elevation of floods were the same, thus:

The year 1828 is from records of March 25, 1851.
" " 1849 " " " " " 28, 1891.
" " 1859 " " " " " 24, 1890.
" " 1862 " " " " " 19, 1890.
" " 1874 " " " " " 18, 1891.
" " 1898 " " " " June 9, 1892.
" " 1899 " " " " March 16, 1891.

There is recorded no gaging since 1892 for flood elevation of 15.9 and 16 feet for years 1898 and 1899 respectively, and the interpolations made are clearly on the side of very greatest possible maximum velocity and discharge for these years. It is most apparent, from the records, that the discharge for later years is much less than in former years for same elevation of flood, as is shown by the records and gagings of the normal flood of 1898, when the elevations were from 15.5 to 15.65 feet, and the maximum discharge was from 1,049,000 to 1,087,000 cubic feet as compared with that of all the great floods from 1828 to 1890, when the ele-

vation ranged from 15.2 to 15.9 feet and the discharge from 1,099,000 to 1,243,000 cubic feet per second.

The record of the gaging on May 4, 1898, shows that with an elevation of 15.65 feet the discharge was 1,049,000 cubic feet with a velocity of 5.97 feet; and it is perhaps safe to assume that the maximum volume of discharge of future great floods will approximate but not exceed 1,400,000 cubic feet per second; hence the elevation of flood on May 4, 1898, to discharge a maximum flood of 1,400,000 cubic feet at 6 feet velocity, with cross-section of 175,600 feet at elevation of 15.65 feet on gage, and assuming the width of river between levees at 4000 feet, would be 14.4 feet higher, or 30.05 feet on gage, and with increasing velocities would be as follows:

Velocity	6.25—12.1	feet	higher	or	27.75	on	gage.
"	6.50— 9.9	"	"	"	25.55	"	"
"	6.75— 7.9	"	"	"	23.55	"	"
"	7.00— 6.1	"	"	"	21.75	"	"
"	7.25— 4.3	"	"	"	19.95	"	"
"	7.50— 3.1	"	"	"	18.75	"	"
"	8.00— 0.0	"	"	"	15.75	"	"

Hence, to secure in 1898 an elevation of flood slope not exceeding 16 feet on Carrollton gage, a velocity of 8 feet per second would have been required to pass the maximum flood volume of 1,400,000 cubic feet, and with a velocity of 7.3 feet per second, and a discharge of 1,350,000 cubic feet, as gaged on May 18, 1897, producing a flood elevation of 18.7 feet, the maximum flood elevation of 1898, to pass this volume at this velocity, would have been only 2.3 feet higher or 17.95 on gage, or 0.75 feet 9 inches lower, which clearly demonstrates that the floods with maximum elevations, even with equal volume of discharge, cannot occur in succession, for the reason that the avenues for passage of water are scoured out by the first flood, and the conditions to retard the passage cannot be formed in the interval of time, between two flood periods. The velocities shown above, and which exist in the Lower Mississippi, are very heavy, and even the lowest is not consistent with any reasonable security of bed or banks, as is shown by the following experiments of Bazalgette, in which he found the velocity required to remove materials as follows:

Fine clay	0.25	feet	per	second.
Sand	0.50	"	"	"
Coarse sand	0.66	"	"	"
Fine gravel	1.00	"	"	"
Pebbles	2.00	"	"	"
Stones, egg size	3.00	"	"	"

And the observations of eminent hydraulicians, as referred to by Gauguillet & Kutter, give mean velocities required to abrade river beds and banks as follows:

River mud	0.33	feet	per	second.
Sand, size of anise seed	0.46	"	"	"
Clay and loom	0.66	"	"	"
Sand, size of peas	0.79	"	"	"
Common river sand	0.92	"	"	"
Coarse gravel and small cobblestone	3.93	"	"	"
Angular flint stone, egg size	4.23	"	"	"
Soft slate	6.45	"	"	"
Stratified rock	7.86	"	"	"
Hard rock	13.12	"	"	"

From which it is not surprising that with a current having a velocity of from 5 to 7.3 feet per second the alluvial banks of the Mississippi River are abraded.

The facts, as presented above, make prominent the further very pertinent question, what will be the rate of increase of future maximum flood elevations? Referring to the above list of great floods, we find that from 1828 to 1874, a period of forty-six years, the increase was only 0.5 of a foot, or at a rate of 0.011 of a foot per year or 1 foot in ninety years, while the flood of 1897 was 3.47 feet higher than the flood of 1874, or a rise of 3.47 feet in twenty-three years, or at a rate of 0.15 of a foot per year or 1 foot in six and one-half years. It will be noted, further, that in 1890 the elevation of maximum flood was 16.1 or 0.4 of a foot higher than that of 1874, or 0.4 of a foot increase in sixteen years, or at rate of 0.025 foot per year or 1 foot in forty years; while the flood of 1890 was 3.07 feet below that of 1897, or an increase of maximum flood elevation of 3.07 feet in seven years, or at rate of 0.44 foot per year, or a foot in about two and one-half years. It is also interesting and instructive to note that the maximum elevation of floods since 1897, while they have been considered as normal, were all considerably higher than those of the great flood periods prior to 1890.

A careful consideration of the facts above presented, showing the increase of elevation of maximum floods, would determine, as conservative, a rate of increase in future of 1 foot in five years, and it is to be feared, and may be expected, that this increase will be exceeded. Hence, unless means are adopted to thwart the gradual increase of maximum elevation of floods, the levees in 1950 will be 10 feet higher than at present, under which condition the whole delta will be confiscated for levee protection, and commerce on the Lower Mississippi will be rendered wholly impracticable.

Mr. Chas. Ellet, who represented the United States Government in connection with river investigation in the year 1851, was sufficiently bold to assert that, to sustain a flood of the intensity of that of 1851, the levees must be made 2 feet higher than they then existed, from Red River to New Orleans; for which assertion he was, in 1861, severely criticised by the United States Government's representatives in charge of river matters. As a matter of fact, the floods of 1851 were no doubt as intense as those of 1897, and while the maximum discharge at Carrollton, as gaged, was 1,186,000 cubic feet per second, and that of 1897 1,350,000 cubic feet per second, the volume passing from the river into the sea between the Red River and New Orleans, was equal to or greater than the difference between the measured discharge; and the prophecy of Mr. Ellet has been more than realized, as in lieu of 2 feet, levees to properly protect the alluvial lands are now fully 5 feet higher than they existed in 1851.

The estimate made by the Government engineers in 1861 for the proper and absolute protection of the alluvial lands along the Mississippi River, from Cairo to the Gulf, in addition to the value of levees then existing, was $17,000,000, and the value of then existing levees was placed at $9,000,000, making the total value of the ultimate and complete levee system $26,000,000. Since 1861 up to the present time, there have been expended upward of $50,000,000, and the levees are yet incomplete; and to properly protect the alluvial lands against inundation in the future, as far as 1950, the levee system alone, if built at once of proper proportions, will cost upward of $100,000,000, but a very much greater amount will be expended by reason of the work of raising and enlarging the levees. This will necessarily be required to be done gradually and oftentimes as an emergency, and at no time will the alluvial lands be absolutely free from danger of inundation, unless the increase of flood elevations is restrained.

The facts above presented, and the conclusion to be drawn, are most thoroughly convincing that the elevation of the surface of normal and extraordinary floods in the Lower Mississippi are increasing, which conclusion presents, in contemplation, most undesirable future conditions and invites our most serious attention.

The methods adopted in the treatment of rivers in Europe, traversing alluvial territory, such as the Rhine, Vistula, Danube and others, cannot be adopted, as these methods have utterly failed in restraining an increase of the elevation of their floods; and, again, these rivers are very small in comparison with the Mississippi; and such measures as would increase, almost imperceptibly, the eleva-

tion of floods in these small rivers would make the increase in the Mississippi River most apparent.

When the "all-levee system" was inaugurated and urged, between the years 1860 and 1880, no marked increase in the elevation of floods was apparent; in fact, the records show an increase of only 0.9 of a foot from 1828 to 1890, a period of sixty-two years; while from 1890 to 1897, the records show an increase of 3.07 in seven years; and the engineering profession, more particularly the Government engineers, in recommending the "all-levee system," did not take into consideration the consequent and serious effect of increasing the elevation of floods, the extent to which this elevation would reach or the disastrous effects resulting therefrom. That this reasoning is correct is established by the fact that in 1861 Captain Humphreys recommended the construction of a levee system as being all that was essential, and estimated that the ultimate cost of protecting the 29,000 square miles of alluvial territory against inundation would be $17,000,000, whereas we have already spent upward of $50,000,000, and, as above noted, will require not less than $100,000,000 within the next forty years, unless the flood elevation can be reduced or maintained at an elevation not exceeding 18 feet on the Carrollton gage.

That the "all-levee system" is a necessity no one can possibly deny; but, as is shown, a levee system without other equally important works will in a few years prove a disastrous failure. It is a matter of universal record that the advocates of the "all-levee system" have persistently condemned all suggestions which would effect, by reducing, the elevation of floods, even when made by prominent, accomplished, brilliant and learned members of the engineering profession; and it is now most apparent that these views must be modified, and such measures considered and adopted as will assist in the matter of reducing the elevation of floods of the Mississippi River.

To refer briefly to the causes producing these high elevations of floods in the Lower Mississippi, it would be pertinent to remark that the power and force embodied in the Mississippi River at high floods are such as to be beyond human hands or brains to combat. The only measures that mankind can adopt, with any degree of success, are those which are in line with nature's laws, and to find the cause it is proper to make comparison between the river, with the "all-levee system" only, as now existing, and alluvial rivers having no levees, and see wherein they differ.

Were the Mississippi River not leveed in, and were no artificial works constructed along its banks, it would, when rising

above its normal bank, overflow, and deposit its sediment on the adjacent banks and the surrounding country. As it gradually elevated its banks and the surrounding country, and gradually withheld the water from overflowing, it would scour a channel of the desired width and depth to convey the volume to the sea level at such velocity as the bed would allow; the elevation of the flood height would be a purely natural one, coinciding with the distance and volume, and the elevation would gradually increase as the river extended into the Gulf, which, under present conditions, is less than 200 feet per year, and in 1000 years would be about 40 miles, or sufficient to raise the flood elevation at Carrollton about 1 foot. According to Government statistics it would take something like 720 years to raise the 29,000 square miles of alluvial territory one foot; so that, if the Mississippi River were left alone, the time would be very remote when the elevation of floods would increase 3.47 feet, as has taken place in twenty-three years, or between 1874 and 1897.

One of the main causes of the increase of flood elevations is the construction of the levees on lines not calculated to maintain a constant cross-section of the river, or especially of that portion of volume which flows above the natural bank; such construction affords an opportunity for the volume to lose its velocity at points where levees are placed comparatively far apart, and thus requires an artificial head to cause the volume to resume its flow through a more confined portion of the river. This elevation of the volumes in the wide portions further reduces the slope and velocity of river above, and, hence, affects the whole river and interferes with any uniform velocity; and, further, the low velocity thus produced at points is sufficient to form deposits and decrease cross-section. This, in turn, causes further elevation of flood surface and produces at other points such intense velocity as to abrade the bed and banks, and oftentimes materially increases the length of the main channel. This is also true of points where the river itself and levees are wide, as compared with other points where the river and levees are narrow, producing relatively low and relatively high velocities, rendering impossible any uniform velocity. Again, there are places where the river is entirely too narrow to properly pass the floods, and some of these narrow points are highly improved, as at New Orleans.

Another cause for the increase of elevation of floods, and fluctuations in elevations for equal volume of discharge, is the changing of the bed of the river and the moving back of levees around bends. This materially increases the distance to ocean

level, and thus reduces the slope and the average velocity, and is further assisted by the great inequalities in the width between levees, providing the conditions above outlined.

Another cause may be found in the accretions which form on the bottom and sides of the channel on the apex sides of bends, without a corresponding amount of abrasion on the concave side, during seasons of normal floods. This condition may increase for a year or two, when a flood with a very high elevation ensues, due less to a greater volume than to the choked or diminished cross-section of river channel.

The combination of all of these causes produces a constant stop and start; retardation and acceleration of velocity, causing excessive accretions at one point, and excessive abrasion at another, cutting out a channel through a choked cross-section at one place and depositing it in a cross-section of superabundant area at another place until it in time becomes choked, and thus the elevation of the floods is constantly varying and steadily increasing, *due to the increase of resistance for channel to clear itself of deposits.* The yearly extension of the river into the Gulf, as affecting the slope, is insignificant and requires no consideration as affecting the elevation of floods, excepting for periods of time as marked by centuries.

That the elevation of great floods is increased by reason of greater volume cannot be conclusively determined in the affirmative. Were the elevation of normal floods not increasing in practically the same ratio as the elevation of the great floods, more consideration could be given to the great increase in the volume of one great flood over that of another.

The careful consideration of the records of great floods for the past seventy years would clearly indicate that the volume is not increasing, and there is every reason why the maximum volume should not increase with the settling up and improvement of the country over that of the great floods which occurred, when the whole country tributary to the Mississippi was wholly unimproved. The opening up and improving of the country has very largely increased the percolation and retention of water on the lands, and the installation of industrial enterprises retains large quantities which formerly were precipitated to the Mississippi immediately the warm season opened. With the further development of the country, this volume, which will be retained and allowed to run off gradually, will greatly decrease the maximum volume of future floods, and even with the worst combinations and most undesirable conditions as to the breaking up of seasons of cold weather, the

maximum volume of future floods should not exceed the maximum volume of the great floods of the past. It is, however, possible, and even probable, that very great future advantage will be secured to the Lower Mississippi by the construction of further works having for their object the further retention of water for irrigation, or other purposes of the territory tributary to the Mississippi, and thus entail a double benefit.

The suggestions as to the methods to adopt in order to secure the very lowest possible permanent maximum flood elevation for the Lower Mississippi (16 feet or less at Carrollton) are replete with material for discussion and consideration.

The first steps toward securing satisfactory results would be to provide a firm base or foundation for such conclusion as may be reached, by the inauguration of measures to secure full and complete data and information of all the conditions now existing which have a bearing on the subject, and to this end it would be necessary to correlate, and place in such shape as can be utilized, all the data secured by the United States Government and the Mississippi River Commission, and all the reliable data which can be furnished by levee boards, levee engineers or other parties, and fill in with the best possible judgment, by interpolation or otherwise, the data covering past conditions which are not attainable, and then proceed to arrange for the securing of accurate data of all the conditions, as to cross-section of channel throughout the whole length of the Lower Mississippi; make complete investigation as to direction and intensity of currents, and of all abrasion and accretion of banks; secure all data necessary to determine positively the cause for any and all of the varied actions of the river, such as accelerated and retarded velocities, shoaling and scouring of bed, accretion and abrasion of banks; also note all the conditions necessary to determine the practicability of the adoption of such remedy as may be determined upon. Make full investigation and survey of all low alluvial lands, note all the conditions necessary to determine as to the practicability of their utilization as relief avenues for the floods, and at the same time assist in making these low lands suitable for future agricultural enterprises; in fact, make the whole investigation as nearly complete as possible, and thus enable the whole subject to be studied and considered in all its phases. This might perhaps result in the adoption of methods, quite inexpensive and most efficient, not thought of now, for the securing of the object sought to be obtained, and at the same time provide very great advantages to industrial and commercial enterprises.

In the absence of full and complete data and information on all points bearing on the subject, or rather in the light of such information as is now before us, it would appear that, to provide proper protection of the Mississippi Delta against inundation, there must be provided, in addition to levee building, a reasonably uniform cross-section of river, especially for the volume flowing above top of natural ground, that the levees should be located to provide this requisite and that future location of levees should be determined by the calculation for volume and velocity of river at any point, for the purpose of providing proper cross-section, rather than by such physical condition as may exist, as is the present practice.

Measures must also be adopted by which the extensive caving, by reason of constant and heavy abrasion of banks in bends, will be measurably retarded. To accomplish this end, the heretofore condemned suggestion looking to the removal of accretions on bends or points can no doubt be practiced with great benefit. The desired requisite to be secured, to maintain a low and uniform elevation of floods, is a channel which is of such cross-section as to flow, with a reasonable velocity, the volumes received. A careful investigation of the channel, after each high water, will give the data necessary to determine by calculation what work will be required in removing accretioning banks, bars or other obstructions to secure the proper channel for the ensuing season.

Should the investigation disclose the fact, which in all probability it will, that at places the river is too narrow and the levees too close, the latter must be removed, and conditions provided by which the river will cut a channel of the requisite cross-section; where choked cross-sections exist at points where valuable improvements are located on the adjacent banks, as at New Orleans, the additional channel area required may be secured by a spill-way extending from a point just above the city and connecting the river at the English Turn; the ends of this spill-way to be located at an elevation of say 13 feet Carrollton gage, or such elevation as may be determined as coincident with the volume, section and velocity safe to pass New Orleans; and the ends of the spill-way to be made of masonry, impermeable to action of water, and thus secure control of the volume it will convey. This spill-way will assist in maintaining a velocity in the main channel past New Orleans such as will not cause the heavy abrasion now sustained by reason of the high velocity required to pass flood volume.

I am of the opinion that the suggestion made by Brigadier-General B. S. Roberts, of the United States Army, to reclaim

waste swamps along the Lower Mississippi by utilizing the delta-making material of the surplus water of the river, will, with some modification, prove most beneficial to all interests, especially the agricultural and sanitary interests of Louisiana; and I am convinced that such measures will also form a most important factor in maintaining a correspondingly low and permanent elevation of floods, will render unnecessary large future expenditure for levee construction and will provide the greatest possible security against inundation, notwithstanding the fact that the Government engineers in charge of the Mississippi River improvements condemned and criticised the suggestion of General Roberts as having no merit.

The measures I would suggest, as modifications of the plan presented by General Roberts, would be such as not only affect the flood slope of the river and vastly improve the lowlands, both from a financial and sanitary point of view, but would further provide an invaluable supply of water for irrigating the land during the low-water season, which is not infrequently accompanied by a long season of drouth. To this end, there would be located, at such points as the survey and investigation would best determine, a spill-way of such construction as to be positively free from danger of washing out, the sill of which to be at such elevation as conditions would determine. This spill-way would be connected, by levees across the high ground adjacent to the river, with a large reservoir or basin constructed directly in the low ground or swamps. The size of this basin would be such as conditions may determine, for illustration, say 10 miles long and 5 miles wide, embracing an area of 50 square miles. This reservoir would be constructed by dredges from the inside and the proper levees would be formed around it to such height as may be determined,—say of sufficient height to maintain the surface of water at an elevation of 5 feet above the high land adjacent to river where the spill-way has ceased to run. At such point as may be desired, in the levee forming the reservoir, will be constructed a spill-way to allow the water from the river to pass directly to the swamps, after filling the reservoir. The surface of the swamps will be gradually raised by the deposits from the river water, and any territory desired can be elevated by construction of small levees to direct the flow after the water leaves the reservoir. Thus, at small expense, the whole territory adjacent to the reservoir will be elevated in a few years. In the course of time, say twenty-five or thirty years, or when sufficient filling has taken place, the spill-way and reservoir could be abandoned and new ones constructed at other points, and thus the alluvial

territory along the river would be constantly elevated, co-extensive with, and perhaps at a greater rate than the increase of elevation of floods from natural causes. The reservoir of the dimensions above referred to, holding 5 feet of water, would contain 6,969,-600,000 cubic feet of water when flood in the river recedes below elevation of sill of spill-way; and this volume of water could by gravity be used to irrigate the adjacent lands during a dry season. On the assumption of there being required for proper irrigation an acre foot or a depth of 12 inches of water over the whole territory to be irrigated, the volume would irrigate 160,000 acres of land, and a low estimate of the value of such irrigation would be $5 per acre, which would aggregate an advantage amounting to $800,000 per annum or 10 per cent. on a capitalization of $8,000,-000, not including the advantages accruing from the elevating of these lands, making them productive, and at the same time removing extensive malarial breeding areas and improving the sanitary condition of the territory.

The dimensions of the spill-ways and reservoirs would be such as would be determined by the survey and full consideration of the location selected. Approximately, the spill-way would be 5000 feet long and would have a maximum capacity of 60,000 cubic feet per second, and it would be judicious that a sufficient number be constructed to have an aggregate maximum discharge of 400,000 cubic feet per second, or say eight in number, located at such points as to cover the low ground to best advantage and make the connecting levees as short as possible. In the main, these large spill-ways and reservoirs should be located on the right bank, as larger areas of lowland lie on this side of the river and the connection with the sea is more direct; although several small spill-ways and large reservoirs could be located to great advantage on the left bank.

Closer investigation and experience will determine the volume which can be, with best advantage, passed from the river to the spill-way, but for economic interest the volume allowed to flow over the lowlands, as proposed, should be as large as possible, and perhaps it may be wise to exceed the volume of 400,000 cubic feet per second above referred to. This may be done without decreasing the velocity in the river sufficiently to form deposits. The volume in the river, when it recedes to the sill of the spill-way, may be most advantageously fixed at such volume as will produce a velocity not exceeding 5 feet per second, or with maximum discharge of about 800,000 cubic feet per second.

As above represented, the annual value of spill-way and reservoir for irrigation would approximate $800,000 for each spill-way having a capacity of 60,000 cubic feet per second and reservoir embracing 50 square miles, which, for eight, or sufficient to discharge 400,000 cubic feet per second, with corresponding reservoir capacity, would amount to $6,400,000 per annum, or 10 per cent. on a capitalization of $64,000,000. The cost of the spill-ways and reservoirs would depend on location, but approximately the cost of each would not exceed $600,000, not including the value of the land occupied.

The foregoing, however, does not represent all of the direct advantages which would be secured. The elevating and reclaiming of the lowland will, in time, produce an advantage of enormous value. Land now worth $1.25 per acre will become the most fertile and productive in the Union, and the crops grown will yield a revenue equal to 10 per cent. on a capitalization of from $50 to $150 per acre.

The suggestion, as will be observed, contemplates the delivery of water on to the lowlands at such velocity and in such manner as will admit of deposits forming adjacent to the reservoir, or at any point desired, by the construction of a small supplemental levee, and obviate entirely the high velocities and the heavy abrasion of land, and uncontrollable points of deposit which are secured by a sill and side levee to the lowland, which is practically a leveed crevasse; and further secure the irrigating reservoirs. It would be pertinent to remark that the irrigation of our lands is a progression which in the very near future will be most fully appreciated, and will be adopted wherever an opportunity offers. For the purpose of irrigation, large reservoirs with small spillways could be placed along the Upper Mississippi.

Allowing that 400,000 cubic feet per second is passed by eight spill-ways and allowed to deposit on low ground for an average period of 120 days each year, and that the water contains, of solids, 1 part in 1500 parts, the deposit per year would be 5 inches deep over an area of 250,000 acres, or 5 feet deep in 12 years, or on an average it would fill 63,470 acres 1 foot deep each year, and in 100 years it would fill 6,347,000 acres 1 foot deep.

Recapitulating the calculations: 400,000 cubic feet per second for 120 days would deliver on the lowlands 4,147,200,000,000 cubic feet of water, and on basis of 1 part solid in 1500 parts, the amount of deposit would be 2,764,800,000 cubic feet of earth, or 102,400,000 cubic yards, or 153,600,000 tons, or 5,120,000 carloads of 30 tons each, and allowing 30 feet to the car would make a

train 29,130 miles long, and if this train traveled at the rate of 30 miles per hour, it would take over 40 days to pass one point.

This illustrates the enormous amount of earth carried by the Mississippi each year and deposited in the Gulf of Mexico. Did not nature intend that the Mississippi River should drain the territory embracing thirty-two states, two territories and a portion of the British possessions, on the principle that the section which was injured or jeopardized, and which required work of protection, would be recompensed at the expense of the territory that sustained benefits with no corresponding injury? And did nature intend the millions of tons of fertile earth carried by the Mississippi to be wasted in the waters of the Gulf of Mexico?

I believe it was intended by nature that the Mississippi River should be the source of very great benefit to mankind, but stipulated that if mankind would receive the full benefit of this river he must use intelligence and exertion, as is shown by similar works of nature. And I further believe that mankind is endowed with all the necessary intelligence to positively avoid danger of inundation of the alluvial lands of the Lower Mississippi, and realize all the benefits of the rich material carried in suspension, by filling in the low places and enriching the whole territory as desired, as also improving the sanitary condition of this section, and the consummation of these most desirable conditions depends entirely on the energy of mankind. Have we energy to help ourselves?

DISCUSSION.

Mr. H. B. Richardson.—This paper announces conclusions as to the height of future floods in the Lower Mississippi River, and the consequent dangers impending, which, if correct, must be regarded as appalling, and may well cause us to join with the author in asking, "Have we the energy to help ourselves?"

When it appears that a "consideration of the facts . . . would determine as conservative a rate of increase in the future of one foot in five years," so that the levees required to restrain the flood "in 1950 will be ten feet higher than at present,"—and presumably twenty feet higher in the year 2000. With an equal increase each succeeding century, we may think the wisest application of our energies to be toward the removal of ourselves and our belongings to regions of greater altitude.

It is some comfort, however, to find the author remarking that "any conclusions reached will be understood as being susceptible of such modification as more full and correct data may conclusively determine to be correct and proper."

And it may afford further relief to examine more carefully the table constructed by the author "to amplify and form a base for the conclusions" presented.

This table, in which we are informed "the history of the great floods is recorded," contains six columns of figures, referring to the gage height, slope, velocity and discharge at Carrollton, of thirteen floods during the period of seventy-one years between 1828 and 1899. The two last columns ("Velocity" and "Discharge") contain twenty-five items, thirteen—that is, 56 per cent.—of which "are interpolated from the records of other years," according to a system of the author's own devising,—namely, by finding, in the reports of the Mississippi River Commission, a gaging of discharge and velocity made at Carrollton at any time when the stage was the same as the highest of the year given in the first column of the table, and filling in the last two columns with the discharge and velocity so found. For instance, as shown in the second table, the author takes from the records of March 25, 1851,—when the gage reading at Carrollton was 15.2,—the velocity and discharge as then gaged, and "interpolates" them for the year 1828, when he says the flood stage, on April 1, was the same. Why the gaging of March 25, 1851, should have been selected for "interpolation" in preference to that of March 22, when the stage was the same, but the velocity and discharge considerably greater, is not apparent. Nor why the "interpolations" for April 25, 1898, should have been taken from the records of June, 1892, instead of March, 1891, when the stage was the same and the observed velocity and discharge decidedly larger. The "slope per mile" given in the fourth column is also "interpolated" from assumed data; so that, after all, the only column of the table that purports to give any real "history of the great floods" is the second,—*i.e.*, "gage reading,"—the third column being simply a variant of the second, produced by the subtraction of a constant difference (0.35) between zero of the gage and mean Gulf level.

From the table so constructed the author proceeds to show the "rate of increase of future maximum flood elevations." For forty-six years of the period included in his table he finds it only a foot in ninety years, while in the next twenty-three years it goes up to the alarming rate of a foot in six and one half years, the last seven years of which period has rushed on at the fearful rate of a foot in about two and one-half years.

He fails, however, to note that during the last two years included in the table there has actually been a *decrease* at the rate of almost a foot in seven and a half months.

Nor does he mention the fact, shown by the table, that the increase from the beginning to the end of the period covered, is only a foot in eighty-eight and three-fourths years, or about the same as that given for the first forty-six years.

And yet the author, after a "careful consideration of the facts presented" in the table, concludes it to be a thing that "may be expected" that an increase of future flood elevations at Carrollton will continue indefinitely at the rate of one foot in each five years.

This can be compared only to the conclusions of another experienced observer—Mr. S. L. Clemens—in which he shows, from the rate at which the river is being shortened by cut-offs, that the corporate limits of New Orleans and Cairo must overlap each other at some future date, not now recalled by this writer, but probably about the same time that the levees here are built ten feet higher than at present.

The author's local experience and observation has covered a period of twenty-one years, and his conclusions are entitled to serious consideration.

But it should be remembered that the investigations of Humphreys and Abbot, reported in their "Physics and Hydraulics of the Mississippi River," covered a period of ten years between 1850 and 1861; and that the Mississippi River Commission has been diligently studying the same problem for over twenty years —or since 1879; both with ample means for surveys and numerous assistants, and that the scope of their operations has included not only all that was to be learned from the surveys and observations at Carrollton and New Orleans, but also throughout the entire river.

The Humphreys and Abbot report gave certain elevations at numerous points along the river, which they considered as probably the highest likely to be reached by any flood confined between levees, not greater in volume than those previously recorded. After the flood of 1874, the Commission appointed by the President to report on the flood of that year, practically adopted the same conclusions regarding the probable flood-elevations. And, finally, the Mississippi River Commission, after some seventeen years of surveys, investigations and studies, adopted a provisional standard of probable flood heights, not greatly differing from the conclusions of its predecessor, though somewhat higher at Carrollton.

No flood has yet come within more than a foot of reaching the latter standard at Carrollton, and only one has reached the mark set by Humphreys and Abbot forty years ago.

Considering the relative opportunities enjoyed by the several investigators for collecting full data and for comprehensive discussion of the whole subject, the present writer is inclined to accept the more moderate conclusions of Humphreys and Abbot and the Mississippi River Commission, rather than the startling predictions of the author.

Mr. B. M. Harrod.—In the paper under discussion the title, "Lower Mississippi," is limited to that part of the river below the mouth of the Red River. It has usually been understood as extending over all parts flowing through the alluvial valley, or wherever its geology and physics are the same.

The phenomena of any one part are explainable only by a comparative study of all parts where similar conditions prevail.

Gage heights are transmitted with substantial regularity from one station to another over any length of the river which is not affected by tributaries or outlets. If either of these disturbing influences intervene between two gages the relation of one to the other is disturbed, and no flood estimate can be based on the lower one without estimating the effect of the intervening disturbance.

Probably the law of the uniform relation of successive gages would, for obvious reasons, be more closely applicable to that part of the Mississippi below Red River than to any other whenever the discharge passing that station reaches the sea, or at least the Fort Jackson gage, without loss. But this has not been the case in any year of large or even of moderate floods until recently. The loss of discharge by crevasses between Red River and Carrollton has always disturbed their high-water gage relation. On several occasions the escape through crevasses amounted to one-third or more of the discharge passing the former station. Under such conditions no conclusion concerning the increase or decrease of floods can be reached by an examination of recorded gage heights at Carrollton without a study of the effect of the crevasses.

The fallacy of any such method of reasoning is shown by an examination of the relative heights of the gages at Red River and at Carrollton during the time that these stations have been carefully maintained and regularly recorded, or since the high water of 1871, a period of thirty years.

The discharge at Red River gage station is the sum of the discharges of the main trunk of the Mississippi, of the Red River and of the overflow, if any, through the Tensas Basin, less the discharge of the Atchafalaya. A certain gage reading at Red River will give, approximately, a certain gage reading at Carrollton, provided there are no crevasses between. The discharge of the Lafourche

is so small, even at flood stage, that it may be neglected in so crude a discussion as this.

In any examination of gage heights, to determine the tendency of floods to increase or diminish, the writer prefers the method of dividing the total period of available records into groups and comparing the averages, rather than picking out arbitrarily the maximum heights in two flood years and assuming that the difference between them indicates the rate of change, without a consideration of modifying condition.

The following are the averages of the three groups of flood heights of ten years each, at Red River and at Carrollton, from 1872 to the present time:

Station.	1872-1881.	1882-1891.	1892-1901.
Red River	41.43	43.77	41.00
Carrollton	12.50	14.57	14.95

It will be observed that the second decade shows an increase over the first at Red River of 2.34 feet, or $5\frac{1}{2}$ per cent.; and at Carrollton of 2.07 feet, or $16\frac{1}{2}$ per cent. The third decade compared with the second shows at Red River a decrease of 2.77 feet, or $6\frac{1}{2}$ per cent.; and at Carrollton an increase of 0.37 feet, or $2\frac{1}{2}$ per cent. The third decade, compared with the first, shows at Red River a decrease of 0.43 feet, or 1 per cent.; and at Carrollton an increase of 2.45 feet, or $19\frac{1}{2}$ per cent.

These figures, including all that are sufficiently complete and reliable for use, indicate no progressive change of importance at Red River, and a considerable but irregular increase at Carrollton. The former gage records the discharge of the valley across the thirty-second parallel, modified only by the distribution of discharge down the main trunk and through the Tensas Basin, while the Carrollton gage has been largely controlled by intervening crevasses.

This exhibit directly connects the increase of high waters at Carrollton, with the improvement of the levee system which followed the organization of the State levee boards and the first extension of Government aid early in the second decade, from 1882 to 1891, and with the continued and increasing vigor with which the work has been pushed, both by the States and general Government, since 1892.

In this connection, it may be interesting to give the record at Cairo, near the head of the valley, as it has been used at Red River and Carrollton. During the second decade the average of high waters was $10\frac{3}{4}$ per cent. higher than in the first; in the third it was

9 per cent. lower than in the second, and substantially the same as in the first decade.

The evidence of any present change in flood heights other than that accounted for by building of levees is entirely inconclusive. The author is of the opinion that the floods of the future will not increase, but may decrease. The reasons given, connected with the breaking up of ground for cultivation and the extension of irrigation, are probably good, as far as they go, for the western tributaries. But it is hard to believe that the extensive deforesting of the western slopes of the Alleghenies can fail to increase the rapidity and thoroughness of the run-off from these mountains, making the high water higher and the low water lower.

The building of levees commenced from small beginnings nearly two centuries ago, and since then has been the only method employed for the reclamation and protection of the alluvial lands of the valley. Since 1850 the levee system has received thorough study and full discussion. Humphreys and Abbot reached a conclusion in favor of a combined system of levees and outlets, but failed to find any suitable location for the latter. Abbot demonstrated the futility of attempting to grade up the lower lands of the valley by deposit from overflow. Barnard, Bailey, Forshey, Eads and many others advocated levees. The discussion occupied many engineers and entered both houses of Congress and their committees. While it raged the people who wanted to live and plant in the river States went on strengthening and extending the levees. It is now the adopted system because it is proved theoretically right and practically useful. Levees have caused no elevation of the bed of the river and no phenomena that were not anticipated, and have developed no insurmountable difficulties. They have at all times been, and they are now, worth every dollar they have cost. So well are those who live behind them satisfied of this that there is no relaxation of effort to complete the system.

Reservoirs may, in certain localities, serve as useful adjuncts for the regulation of high and low water discharge, for irrigation or perhaps for sedimentation, but their use will be limited by the want of suitable physical conditions and their great cost.

General Barnard, who was not only one of the ablest advocates of the reclamation of the alluvial valley by levees, but also the first and for a long time the only United States engineer who advised the improvement of Southpass by jetties, thus expressed himself in a criticism of General Ellet's plan of outlets:

"The idea that levees have any tendency to cause a rising of the bed is so simply absurd, so destitute of a single reason to justify

it, that it hardly seems necessary to allude to it. It is the want of levees, and that alone, which can cause such a rising, and in proportion as the water is let out from its confinement by levees, by means of crevasses or 'outlets,' will the bed of the Mississippi River be elevated.

"There is but one protection to Louisiana, and that is levees; outlets or lateral vents of any kind may be discussed, adopted by State authorities, perhaps attempted. If so, they will certainly deluge the unfortunate district through which their discharge is carried, while they utterly fail to relieve the river; producing, on the other hand, deposits in its bed, which they will eventually raise, and with it the surface.

"In brief, to take waters from the river channel and to throw them into the lateral basins, lakes and bayous is to take them from the channel by which they can, with the most ease and safety, be carried to the sea to put them into basins unsuited by their slope to carry off the floods thrown upon them."

Mr. William Joseph Hardee.—Before entering into a discussion of the paper before us, the writer desires to apologize to the members of this Society for imposing on their time, and to beg their indulgence if what he has to say upon the subject is as extended or more extended than the original paper. The subject is a most vital one to the inhabitants of the alluvial valley traversed by the Mississippi River, and should not be lightly dealt with. To reach intelligent conclusions in the matter of flood heights necessarily involves the investigation of a very large field.

The harsh impeachment has been breathed that those engaged in the works of river improvement are perforce, for self-protection, banded together in supporting with great unanimity the methods being employed through apprehension that they might, like Othello, find themselves with their occupation gone. Such charge cannot be made in the case of the writer, as he is not now and may never again be identified with Mississippi River improvements. He feels, however, that his long connection with those works and his experience of many years spent in working on the river entitle his opinion to some weight without question as to his motives.

There is so much fallacious reasoning in the paper before us, appealing strongly as it does not only to the layman, but to the inexperienced engineer as well, that the writer feels it a duty he owes to the community in which he lives to exercise his best effort to defeat the circulation and acceptance of such unsound doctrines.

There are to-day but few, if any, subjects more perplexing to American engineers than the one of economically controlling the Mississippi River with respect to maintaining adequate depths for low-water navigation; providing against the destruction, by caving

banks, of valuable improvements situated in close proximity to its shores, and protecting against overflow the lowlands in the valley through which it flows.

The subject is, unfortunately, one in which not a large number of engineers are directly interested, and it has therefore challenged the attention of not many and the close and devoted study of but few.

No reliable conclusions concerning that part of the subject relating to increasing flood heights can be deduced from a study of the river at any one particular point, or of a very short length of it. The investigation should properly cover the entire length of the river from Cairo to the Gulf, for the purpose of disposing of matters of general bearing and influence; and then there should be considered a stretch of river, ranging from 100 to 200 miles in length, throughout which the levee line is continuous on both banks and no tributary streams occur to exert an extraneous influence. Consideration of a long length of river is essential to eliminate local vagaries and afford net results.

He who undertakes to study the Mississippi River intelligently soon finds himself in such a maze of ramifying data, many of which are apparently inconsistent or seemingly contradictory, that unless he be patient and persistent he will soon abandon his investigation.

After a careful consideration of the paper before us, the writer is forced to the conviction that its author undertook to discuss his subject with a preconceived *theory*, and in an endeavor to establish the correctness of that theory he has either failed to make proper research to inform himself fully or else he has ingeniously avoided reference to and consideration of such data as are properly germane to the subject, reviewing and employing only such data as he believed would support his theory. As far as employing data is concerned, he fails to go beyond the Carrollton gage, using only some controvertible data acquired at that gage upon which to base his theory. Where he does venture beyond the Carrollton gage his conclusions are mere opinions, unsupported by even apparently trustworthy data. The writer has already stated that reliable conclusions cannot be arrived at by a consideration of the river at one point only, as he will later on endeavor to demonstrate. He is so impressed with that belief that, on such account alone; he would disregard the conclusions reached by the author, no matter how well such conclusions appear to be supported by apparent facts. The author, fortified with specially selected data, endeavors by fallacious argument to prove that his "theory" is a "condition," predicating his conclusions principally on a comparison of dis-

charge observations measured at the Carrollton, La., station, propped up by some alleged but unproven facts, and some admitted facts so unimportant in effect as not to possess appreciable bearing on the subject. And, having satisfied himself and ostensibly his readers, that dire calamity threatens the Mississippi River Valley in the near future, he exhorts us to employ our best endeavors to discover some avenue which promises relief in a measurable degree, describing a general plan by which he believes adequate relief may be secured.

As the writer cannot admit that a calamity threatens, he will not indulge in a discussion of relief measures, but will confine his attention to a disproval of the conclusions reached by the author.

It may not be out of place, at this time, to remark that the question of utilizing the sediment carried by the waters of the Mississippi River for the upbuilding of the lowlands in the alluvial valley is one which is not altogether without merit, but the writer feels that it is a matter which time and circumstance will develop. The cost of the work incident to such an accomplishment would at this time so far exceed the value of the lands reclaimed as undoubtedly to render the project impracticable. The population of Holland averages 401 persons to the square mile, and such density of population enhances the value of land to a degree which justifies the large amount of money invested in dikes, extensive drainage canals and gigantic pumping stations to reclaim the land and protect it against inundation.

In Louisiana, the fifteen riparian parishes in the alluvial valley, the parish of Orleans included, average 71 persons to the square mile. In some of the parishes containing the largest areas of very low lands, the population per square mile is as small as 7 to 19 persons. Considering the present small value of lowlands in the alluvial belt, and the large tracts of cheap land available there for cultivation, it may be readily appreciated that our country has not yet reached a stage in its existence at which the expenditure of large sums of money is justified in reclaiming low, ill-drained lands. When such time arrives, some method, perhaps along the lines suggested by the author, will be employed to render lowlands available for agricultural pursuits.

From the writer's knowledge of how discharge measurements are conducted, gained from personal observation, he is confident that not even approximate reliance can be placed on the results obtained. Discharge measurements should be disregarded for purposes other than general approximations. They should never be employed to govern conclusions based on differences shown by a

comparison of results obtained at different periods for the same station or close analogy of results obtained at different stations. There are so many opportunities for accidental error which cannot be easily detected, that error of result is likely to range as high as 25 per cent. This opinion is shared by many of the officers of the United States Engineer Corps, under whose direction discharges of the Mississippi River are measured, as the writer knows from their personal expressions to him.

To illustrate the unreliability of the discharge records quoted by the author, and incidentally for the information of those members of the Society who may not be familiar with the detail work embraced in measuring those discharges, the high-water depths of the river being as great as 180 feet, the following description of the crude method commonly employed in the past is furnished:

Depths of water were measured with a cotton rope line weighted with a 7 to 20-pound weight of lead, depending on depth of water and velocity of current; velocities were measured with a Price self-registering current meter. In the early days, before a current meter was invented, velocities were determined by means of surface floats floating over a fixed base line. Both the soundings and velocities were measured from a steam launch of small size, which could be rapidly maneuvered.

The point at which the discharge is measured is usually designated as a "discharge station." At the station, a cross-section of the river is established on a line projected as nearly as practicable at right angles to the general axis of the current. The contour of the submerged portion of the cross-section is developed by a number of soundings taken from a steam launch moving backward and forward across the river a number of times. Sub-stations on the cross-section are then established at points marking the angles in the wetted perimeter. To minimize error, in the instance of long planes in the wetted perimeter, the sub-stations are established not further apart than 200 feet.

The depth of the river and the velocity are measured at each sub-station. The depths and mean velocity at adjacent sub-stations are averaged, and then multiplied by the distance between the sub-stations, thus determining the discharge, for any desired unit of time, for that particular division of the cross-section; the several sub-divisions are afterward summed up, and the total discharge for the station thus determined.

On the line of cross-section, on both banks of the river, there are placed, several hundred feet apart, two prominent targets, furnishing a range to guide the boat in taking position on the cross-

section. Sub-targets are located along the bank of the river on the upper side of the discharge station, two of which form a range, and so placed, as to position, that a projected line through them intersects the cross-section line at a sub-station. The targets, of course, are marked differently, so as to be readily distinguished by the observer on the boat.

The boat is moved to a point slightly above the sub-station to be measured; and, when it starts floating with the current, the lead is heaved and the boat either worked ahead or backed, as may be necessary to keep the lead line in vertical position and alongside of the boat. As it is difficult, after the lead has once touched the bottom, to maintain it plumb for any length of time because of deep water and strong current, it is important that it shall be cast just far enough above the line of cross-section to assure its reaching plumb just as the sub-station is reached.

It will be observed that there are two rather difficult points involved in determining correct depths. To begin with, the boat must be skillfully handled, and great care must be taken that it crosses the sub-station at its proper location, which circumstance can be determined only by the boatman through the intersection of the sub-range line and the main cross-section line. This is not easy to accomplish when it is remembered how easily a small light craft may be influenced by wind and current. The boatman must also take into account the depth of water and the velocity, to guide him in determining just how far above the station to go, and what position to take with respect thereto, to get his boat in shape for casting the lead, in order that the boat may cross the sub-station just about the time the lead line becomes plumb.

Each day, before sounding is commenced, the lead line is soaked for half an hour or so in water, then taken out, stretched and verified. It is always long or short, and the difference must be determined for different depths and applied as a correction to the depths measured.

On many occasions the writer has personally directed soundings of the Mississippi River, and on some occasions has himself handled the lead line. From his observations and personal experience he is certain that in depths ranging from 100 to 160 feet of water, flowing at a velocity of from 5 to 7 feet per second, it is impossible to secure a plumb lead line. There is always a considerable amount of swag throughout the center of the line; just how much cannot be determined, but certainly of sufficient amount to affect the correctness of the sounding.

Before commencing a series of discharge observations, the current meter is rated. This is accomplished in slack water by dragging the meter with a boat a number of times over a fixed base. The mean of a number of observations is taken as the fixed relation between a revolution of the meter wheel and a lineal foot. As it would be impossible, with the use of one boat and one meter during the day (the time in which a discharge must be measured) to measure the velocity at a number of depths on each sub-station, which should properly be done in order to secure close results, the inventor, Mr. W. G. Price, then United States assistant engineer, personally directing the discharge observations at the Carrollton station, after much study and innumerable observations, fixed, for depths of less than 20 feet, 0.4 of the depth below the surface as a point at which the mean velocity occurs, and, for depths in excess of 20 feet, 0.6 of the depth below the surface as the point at which the mean velocity occurs.

To one having knowledge of the Mississippi River, who will pause to consider the general turbulence of the flow of its waters, the number of cross-currents, boils, eddies, etc., it does not seem reasonable that the mean velocity should really occur at the depths above described. In the opinion of the writer, this arbitrary use of a fixed percentage of depth, without allowance for local conditions, at which to measure mean velocities, contains considerable element of error.

In measuring a discharge, the first thing done, after checking the lead line, is to make one sounding at each of the sub-stations. If the sounding corresponds closely with the depth found on the preceding day, the boat passes on to the next sub-station; but if any considerable difference be found, a number of additional casts of the lead line are made, in order to verify the sounding and make certain that some change of depth has taken place since the preceding day.

The writer is informed by assistant engineers, who have measured discharges at the Carrollton station, that differences as high as 4 feet have been noted from day to day at a sub-station. Since depths are measured at the sub-stations only, no determination is made of changes, if any, between sub-stations. It will be observed that in this respect there is opportunity for considerable error in the area of that sub-division of the cross-section.

When the depths throughout the discharge section have been determined, the boat takes position in turn at each sub-station. The machinery is worked ahead, just sufficiently strong to overcome the current and maintain the boat in a fixed position; the

meter is then lowered to proper depth, and usually is operated for three minutes. The total number of revolutions is registered on a gage on the deck of the boat, the observer closely watching the gage to see that the meter is running evenly. By reducing the total number of revolutions to the equivalent per second and applying the meter rating, the velocity of that sub-station is determined. The opportunities for accidental error in this part of the work of measuring the discharge are not small. The observer must trust to his boatman to keep the boat steady and in proper position, and, as has been stated, it is doubtful that the depth used is the point at which the mean velocity really occurs. Further, the meter is rated but once during a season; its mechanism is delicate, and likely, at any time, to become deranged, affecting all reductions based upon the original rating. It must also be stated that the position of sub-stations is not altered from time to time to meet occurring changes in the bottom of the river.

It would seem almost certain that, with such great opportunities for error, considerable error does occur. The writer is aware that in the past some of the observers have been almost criminally careless in the performance of their duties. He knows of one observer, whose work forms part of the records of the Mississippi River Commission, who, through an entire series of discharge measurements never had a lead line cast after the contour of the cross-section was first developed; he contented himself with merely applying the change of gage height to the original depths. A canvass of the records and the inconsistencies found, alone proved that the discharge measurements are not reliable within close limits.

In 1880, June 12 and June 16, Carrollton gage registered 7.6 feet; in the former instance the discharge was 581,000 cubic feet per second, whereas it was only 553,000 cubic feet per second in the latter instance.

Again in 1851, July 2 and July 19, Carrollton gage registered 12.2 feet; in the former instance the discharge was 805,000 cubic feet per second, whereas it was 856,000 cubic feet per second in the latter instance.

Again in 1883, April 28 and May 1, Carrollton gage registered 14.2 feet; in the former instance the discharge was 972,000 cubic feet per second, whereas it was only 941,000 cubic feet per second in the latter instance.

Again in 1890, March 6 and 7, Carrollton gage registered 15.2 feet; in the former instance the discharge was 1,175,000 cubic feet per second, whereas it was only 1,128,000 cubic feet per second in the latter instance.

The difference in the discharges for the same gage reading may be due to error of measurement or they may be due to natural changes in the cross-sectional area caused by a rising or a falling river. It does not matter to which cause the difference is chargeable, the fact remains that a discharge determined at a gage reading on a particular day cannot be relied upon as being the same for a similar gage reading at some distant date, a fluctuation of gage height having occurred in the interim.

It will be noted that the author of the paper under discussion rests his case almost entirely on conclusions reached through a comparison of discharge measurements. The writer believes that in doing so he has committed a grave error, because not only are the records in that respect faulty, but if they were absolutely correct his case would still remain unproven, since a change in the carrying capacity of the river cannot be established by observations taken at one point only. The discharge is controlled not by the gage height only, but also by the slope existing at the time and place of measurement.

It is a law of hydraulics that, if, during a given period and over a given length of river, there has been no net loss of cross-section, and if the elevation of water at the upper end should be increased while at the lower end it remains constant, there will follow increased slope, producing increased velocity, and consequently increased discharge.

The writer, therefore, believes that the author, in seeking to determine whether less discharge occurs at the same or greater gage heights, should have altogether disregarded a comparison of discharges measured at one point only, and should have given his attention to a determination of the changes that have taken place in the carrying capacity of the river.

One of the peculiarities of the Mississippi River is the rapidity with which the area of a given cross-section will vary under the influence of changes in the axis and velocity of the current caused by a rise or fall in the river and a variation in the amount of sediment it is carrying. The records abound with corroboration of that statement.

On a given cross-section the bottom will, to-day, scour in places and shoal in others. Within the short interval of a few days that result will be found to have been reversed, the abrasions having disappeared and accretions beyond the original elevation having occurred, and *vice versa*. At times a net increase and at other times a net decrease of cross-sectional area will be noted.

An increase or decrease of cross-sectional area at one point may be compensated by a corresponding change in the cross-sectional area at a point a short distance below.

It may also occur that there will be either a net increase or a net decrease of cross-sectional area throughout a short length of river, so that, to determine what change in the carrying capacity of the river, if any, has taken place, a long length of river must be considered, and its experiences gathered at about the same gage heights noted, to eliminate local vagaries; in such an instance the net result may be accepted as conclusive evidence whether or not the carrying capacity of the river has remained the same, or whether it has increased or decreased.

The author of the paper under discussion alleges that the carrying capacity of the river is steadily decreasing, which, in his opinion, forces any given volume of water to attain a higher elevation in passing a given point. A similar allegation has many times been made by many persons.

The Mississippi River Commission, in search of light and truth on the subject, and for its information and guidance, had an investigation made by its principal assistant engineer, Mr. J. A. Ockerson, of the 202.7 miles of river extending from Riverton to Vicksburg. Within that distance 554 cross-sections, which were measured during low water in 1881-1882, were measured during low water in 1894 for purposes of comparison. Mr. Ockerson's report, entitled "Comparisons of Cross-section Elements of the Mississippi River," was published by the Mississippi River Commission, from whom a copy may be obtained, and members will find it very interesting. Referring therein to his investigation, Mr. Ockerson says:

"In order to separate the results for pools and crossings, the river has been divided into a series of sections in such a way that the results for the pool sections and bar sections have been summed separately. This is done to detect, if possible, any difference in movement of bed under the two conditions of pool and bar."

After a most careful analysis and review of the subject in a report covering twenty-nine pages of closely printed matter, Mr. Ockerson expresses the following conclusions:

1. The channel capacity in 1894 was greater than in 1881-1882, due to changes above the low-water line.

2. The crests of the shoal bars in 1894 were, on the whole, lower than in 1881-1882. This refers to the actual elevation of the bottom and not to the top of water on the bars.

3. The maximum depth of pools was generally less in 1894 than in 1881-1882.

4. The thalweg depths were, on the whole, less in 1894 than in 1881-1882. That is, a little more than one-half of the length of the river under consideration, and also the average of the sections, shows an elevation of the thalweg or raising of the bottom. A large percentage of this raising occurs in the pools.

5. The high-water bars lying between the medium and bank-full stages have been cut down an average of something over one foot.

6. The general tendency seems to be toward a channel more uniform in depth and of greater capacity.

The author of the paper under discussion charges diminution in the carrying capacity of the river to the three following principal causes:

1. Construction of levees on lines not calculated to maintain a constant cross-section of that part of the river above the natural bank.

2. Moving back of levees around caving bends, thereby materially increasing the distance to ocean level.

3. Diminution of channel by accretions on the sides and bottom of the river on the apex side of bends without corresponding abrasion on the opposite side.

Referring to reasons 1 and 2, it may be stated that, by actual measurement at the office of the United States engineers in this city, from Baton Rouge to Carrollton, the average distance the levee line is removed from the natural bank on the west side of the river is 358.68 feet and 340.26 feet on the east side, making an aggregate of 698.94 feet of batture, or foreshore, between the natural bank and the levee line.

It is a well-known fact that the flow of the river over the battures or foreshores is largely obstructed by eddies, spur levees, vegetation, and other obstacles. If, however, we apply, to this width of say 700 feet, an extreme depth of 5 feet and an extreme velocity of 4 feet per second, we shall have the small amount of 14,000 cubic feet of water flowing above and beyond the natural banks. The amount is an inconsiderable part of a discharge so large as a million or more cubic feet per second. In fact, the flow over the battures is rarely measured and included in the discharge recorded for a station.

It will scarcely be denied that, in the three respects cited by the author of the paper before us, the length of river, from Riverton to Vicksburg, possesses more favorable elements for proving the cor-

rectness of the author's arguments than does the river from Baton Rouge to Carrollton, a length of 125 miles, which is as great a length above Carrollton as can be reasonably counted on as exerting an influence on the gage at that place.

Between Riverton and Vicksburg the river is made up of a succession of deep bends, with little or no length of straight river between the bends; the levees are anywhere from a few hundred feet to five miles or more from the natural bank, since, when rebuilt to meet the demands made by destructive caving banks, they are retired to a distant location. That length of the river is very variable. The bars build up rapidly, and middle ground bars form, splitting the channel and tending to obstruct the flow of the river.

On the other hand, the river between Carrollton and Baton Rouge is fairly straight; there are but few sharp bends and many long lengths of straight river. The levees are quite uniformly removed from the natural bank, there being but one point, Bonnet Carre, at which local conditions force an unusual retirement for a length of about a mile, and the retirement there does not exceed 2600 feet. Levees which must be retired because of caving banks are rebuilt on locations but a few hundred feet distant. The length of the river is almost constant. The bars do not build up rapidly, and serious middle ground bars obstructing the flow of the river are rare and never extensive. If, in a length of river where all things combine to favor the author's theory, that theory fails, does it not stand to reason that it must fail when the circumstances are less favorable?

The writer at least believes so, and he is further convinced of the soundness of his opinion, that the carrying capacity of that part of the river which might exert an influence on the Carrollton gage has not diminished, by a consideration of the conclusions reached, after careful investigation and analysis, by Major Geo. McC. Derby, Corps of Engineers United States Army, in charge of the work of improving the Mississippi River.

The writer had the pleasure of assisting in that investigation, which eventuated in a report dated March 16, 1900, addressed to the Mississippi River Commission, from which the following excerpts are taken:

"In general it may be said that any study of the relations of gage heights, while exceedingly interesting, is apt to be on the whole rather unsatisfactory; the number of variables in the problem is so very great that the mind is baffled in its efforts to keep track of them, and at the end remains unsatisfied as to the soundness of the conclusions reached. It fortunately so happens, however, that there is one long stretch of the Mississippi River, where, through

natural causes many of the variables of this perplexing problem have been eliminated; this tempting field for investigation is of course the stretch of 200 miles lying between the mouth of Red River and New Orleans. At the next gage below New Orleans the flood heights are so low and the mouth of the river is so near, that the tides of the Gulf, small as they are, are sufficient to introduce perplexing complications; while above Red River, outlets and tributaries combine with all the other uncertainties to make the problem as difficult as it well can be. Between Red River and New Orleans there are practically no tributaries, and but one small outlet; the length of the river is about constant; the levee system is less variable than elsewhere; and the effect of the tide at the Carrollton gage is so slight that the height of the river may be assumed to be controlled entirely by the stream of water coming from above, unaffected by variations of level having their origin below.

"During the flood of 1897, which broke the high-water record at every gage in the Fourth District, I was a good deal surprised and impressed by the fact that the first gage to exceed its previous record was the lowest one,—namely, the gage at Fort Jackson, the next was the Carrollton gage, and so on up the river to Red River Landing, where the gage did not exceed its previous record until sixteen days after the Carrollton gage had done so.

"What was scarcely less surprising was the fact that when the Carrollton gage reached its former maximum (17.45) the gage at Red River Landing still lacked 1.6 feet of the height which in 1893 had produced that maximum.

"Both of these remarkable facts point *at first sight* to the much-looked-for raising of the bed of the lower river, with the consequent increase of flood height, which so many have claimed to be the ultimate effect of levee building.

"Before attempting to seek the cause of these phenomena it will be well to ascertain first whether they represent merely curious anomalies peculiar to the flood of 1897, or whether they indicate any well-established tendency to a change in the regimen of the river."

Tables are submitted showing the ratio between the Red River Landing and Carrollton gages for all the flood waves that passed the former place at stages of about 45.2, 43.6 and 39.3 respectively.

Continuing, Major Derby says:

"More evidence to the same effect could be adduced, but the above seems to be sufficient to establish clearly the proposition that the striking feature of the flood of 1897 under discussion, was not something abnormal, but that, on the contrary, such a change in the regimen of the river has actually taken place that we must now expect that any flood wave passing Red River Landing at a high stage will cause a flood wave at Carrollton a foot or more higher than a flood of the same height at Red River Landing would have caused fifteen or twenty years ago.

"Now, if this is actually a fact, it must be due to one or more of the three following causes:

"1. A raising of the bed of the river below Carrollton, causing a decrease in the carrying capacity of that portion of the river.

"2. The effect of crevasses and their closure.

"3. An increase of the carrying capacity of the river between Carrollton and Red River Landing.

"I will consider each of these possible causes in turn.

"1. Has the bed of the river risen?

"If the apparent increase in the flood height at Carrollton is due to the filling up of the bed of the river below, it is manifest that such an effect would be proportionately more noticeable in the case of a low flood wave than it would be in great floods.

"I accordingly submit tables showing the gage readings for many small flood waves which passed both gages well within the banks of the river, a type of waves which usually receives but little attention, but which is in some respect more instructive than the greater waves.

"An examination of these tables not only shows that the apparent increase of flood height at Carrollton is not more noticeable at low stages than at high ones, but it reveals, on the contrary, no trace whatever of any such apparent increase.

"I conclude that whatever else the apparent increase of flood height at high stages may be due to, it is certainly *not* caused by a rise of the bed of the river below Carrollton."

Major Derby also shows that the results observed are not due to crevasses, and, continuing, says:

"If we are right in the conclusion that the apparent increase in the relative height of the Carrollton gage is not due to the filling up of the bed of the river below, nor to the effects of crevasses above or below, there must have been an increase in the carrying capacity of the river above Carrollton, the following tables, with the others already given, show that this increase in carrying capacity must have taken place at such a height in the bed of the river as to manifest itself only at stages above 27.0 on the Red River Landing gage (highest gage record 50.2).

"In the annual report of the Mississippi River Commission for 1899 the surveys made between Red River Landing and Donaldsonville are discussed with results which are corroborative of the above discussion of the gage readings, the conclusion having been reached that the comparison of the results of all the surveys seems to show conclusively that there had been a general tendency to the permanent enlargement of the stream *above the low water line,* and the capacity of the river to discharge its flood waters has been more than maintained.

"The practical effect of this increase of the carrying capacity of the river between Carrollton and Red River Landing is to diminish the high-water slope, so that a flood wave producing a given height at the Carrollton gage would pass Red River Landing to-day at a level several feet lower than would have been the case fifteen or twenty years ago. In other words, since the crevasses have been closed and the levee line maintained with few

or no breaks, there has been a notable decrease of flood height at Red River Landing, amounting apparently to 3 feet or more."

Observe that Major Derby conclusively demonstrates that the carrying capacity of the river has decreased neither above nor below Carrollton; that, on the contrary, there has been a well-defined tendency toward enlargement.

The writer had plattings made of the only five cross-sections of the river, at the Carrollton discharge station for which reliable records are accessible, and the areas below the zero of the gage computed, with the following result:

Year.	Gage height.	Area below zero of gage.
1883	15.4	137.178 square feet.
1891	14.8	144.153 " "
1893	17.2	151.881 " "
1895	2.0	143.750 " "
1896	6.1	143.785 " "

This table certainly shows no evidence of a progressive decrease in the cross-sectional area, but rather the reverse, as we have, in 1895 and 1896, at a low stage, a greater area than we had in 1883 at a high stage. But, as has been stated earlier in this paper, the elevation of the bed of the river at any given cross-section varies from day to day, as the river rises or falls; and, whether or not the carrying capacity is increasing or decreasing, can be ascertained only by determining the net change in a long length of river.

One of the most remarkable of the statements in the paper under discussion is that the development and improvement of the watersheds of the Mississippi River and its tributary streams will decrease the maximum volume of future floods. The writer has always believed—in fact, has never before known the proposition to be challenged—that the deforestation in the great watersheds and the improved drainage of lands there, must necessarily cause retention of less of the rainfall by the soil, but will affect its more rapid delivery to the main drainage arteries, resulting in not only greater volume in the Mississippi, but temporary increased height, because of the rapid assemblage of waters in that stream.

The author of the paper under discussion finds great comfort for himself, and support for his theory that the levees must be raised not less than 10 feet higher than at present by the year 1950 in what he designates as the bold assertion of Mr. Chas. Ellet, made in 1851, to the effect that the levees would have to be raised 2 feet higher than they then were to restrain successfully such a flood as occurred in that year. There is no evidence to show that Mr. Ellet reached that conclusion through the reasons assigned by the author. It is

more likely that he had a more intimate knowledge of the Mississippi River than did his associates, and that he was wise enough to realize that 2 feet additional height of levees was a fair estimate of the requirements to retain between the levees such a flood as that of 1851 and to care for such volume of water until such time as the energy of that flood, augmented by the energy of others to follow, would increase the carrying capacity of the river.

Had Ellet known that the immense low-lying basins in the alluvial belt would be rapidly leveed at some comparatively early date, he would doubtless have expressed the opinion that the levees would have to be raised five or more feet instead of two to successfully carry between them to the sea such floods as that of 1851.

The author of the paper before us says that the Government engineers, in recommending the "all-levee system," did not take into consideration the serious effect of increasing the elevation of floods, etc. In this he is mistaken. In 1880, when the Mississippi River Commission first came into existence, it was without anything like complete and reliable data upon which to base its future operations, nor was it equipped with funds for levee work. From time to time, as far as its funds would permit, it joined the local levee organizations in the general work of restoring and maintaining the continuity of the levee line to a grade one foot higher than the highest previously known water. It was fully recognized, at that time and since then, as the transactions of the commission will show, that the grade used was forced by economy. It was deemed advisable, since the levee system would be no more efficient than its weakest lengths, to restore the entire system to some practicable grade, rather than to have gaps in the line and some lengths of such comparatively extraordinary height as not to render maximum service for years to come. As soon as the continuity of the levee line was re-established and there were funds with which to improve the existing system, the commission adopted a provisional grade as the next practicable step to which to advance the height of the levee line. About that time the extension of the levee system along the fronts of previously unleveed immense alluvial basins was undertaken, and has since been continued. This extension of the levee system produced a change of flood conditions, which made it very difficult to answer with precision the question of a grade competent to care for future floods. The problem would have been more easily solved if only the retention of flood waters between the then existing levees had to be dealt with, but the introduction of the new factor, the leveeing of new basins, made the problem more perplexing.

Future flood heights and ultimate levee grades were the subject of much discussion by the members of the Mississippi River Commission and eminent levee engineers, Captain Townsend, of the Army Engineer Corps, and the late Major Wm. Starling, of Greenville, Miss., contributing valuable papers, which will be found in the Transactions of the American Society of Civil Engineers.

When the levee line had been nearly uniformly raised to the first provisional grade and the system had been considerably extended, the greatest flood of record, 1897, occurred. From the observations derived from that flood, a new grade was adopted, which it is confidently believed will meet all future requirements, except probably a most extraordinary coincidence of maximum rainfall in the valley of the Mississippi River and its tributary streams.

The author of the paper under discussion appears ignorant of the facts just related, and overlooks the effect exerted on flood heights in the lower river by increased flood heights in the upper river, which were anticipated and produced by causes easily comprehended.

One of the good arguments advanced in support of levees lowering flood heights by increasing the carrying capacity of the river, is contained in the following paragraph in the paper under discussion:

"Were the Mississippi River not leveed in or no artificial works constructed along its banks, it would, when rising above its normal banks, overflow and deposit its sediment on the adjacent banks and the surrounding country, and as it gradually elevated its banks and the surrounding country, and gradually withheld the waters from overflowing, it would scour a channel of the desired width and depth to convey the volume to the sea level."

If the river will do, naturally and by slow degrees, what the author says it will do, why should it not do so just as effectively, yet more rapidly, with the assistance of artificially elevated banks?

The writer is firmly convinced that the levee system is a success; that it is performing its mission well, and will continue to do so; that it will in time prove the means of increasing the carrying capacity of the river; and, that floods of a given volume will pass to sea level at lower elevation than formerly.

Mr. Sidney F. Lewis.—In the study and solution of the problems of the Mississippi River, the engineer has to depend more upon facts, and the relations they bear to one another, than upon any fundamental principles to guide his work.

He must analyze and classify all the reliable data on the subject in order to obtain these relations of fact before he can ven-

ture to build a theory. We recognize the value of the three principal mechanical laws as applied in hydrodynamics, the A, B, C, as it were, of the subject, which make up the theory of flow, as expressed in the formula, "Velocity of flow in a stream varies directly as the square root of the product of its hydraulic radius (the ratio between the sectional area of the part of the bed it occupies, and the frictional or resisting surfaces bounding it, known as the wetted perimeter) by its slope (the ratio between its fall and length)" as of prime importance to the engineer who lays a pipe or builds a conduit, for by this formula he can determine the form and set the slope, and the resulting flow will be the one thing that he wants to know; but the flow in a sedimentary stream, like the Mississippi River, makes its own form, and that a very irregular one, and so distributes its slope that it may be almost all concentrated at a certain point at one stage, with little or none there at a different stage. Here there is not much use in trying to express the velocity by $V = C\sqrt{RS}$, for R and S are more difficult to measure than V.

Those of us who are more familiar with the vagaries of this river, and who are employed daily in its observations and operations, know that the "guess and allow," the "average judgment" and the "personal equation" figure immensely in the determination of C, the experimental coefficient.

The author of this paper by his ingenious methods of interpolation and interpretation from his point of view of the relation of certain gage readings, velocity, slope and discharge observations in some thirteen high water years, all of which he calls great floods, builds up a theory and arrives at conclusions, which, to say the least, are appalling, and well worthy of all our energies to thwart and prevent. We live, however, in that consolation which the author metes out to us, when he informs us that this dire calamity, at a rate of one foot increase of elevation to the levees every five years, will take place in 1950. The writer would suggest to the younger members of this Society, who will have passed the age of three score and ten allotted to man, that when that momentous day arrives, they gather all the literature on the Mississippi River, instruments and other paraphernalia, and go to the then existing mountains on the New Orleans front, and offer them in sacrifice to the deity of the "Father of Waters," and further invoke the Almighty, of whom it is written that He created this universe in six days, and that after resting on the seventh, in the contemplation of His great work, He concluded that all was well with one excep-

tion,—He had failed to complete the Mississippi River. To man, made in His own image, He has relegated this task, and if it be beyond the brains and ability of man to master it, why let us pray to Him for a second "Appalachian Revolution," so that He can correct His first mistake, and turn the flow of this great river up stream toward the North Pole instead of the Equator, for it is the shortest distance by that route to the center of the earth.

The writer is inclined to be optimistic in his views. He believes that the universe, being the work of an infinitely perfect being, is the best that could be created; and with regard to levees, they were not built out of theory, but are an evolution from a matter of necessity.

Those "well-banked potato rows" which the author speaks of in the introduction of his paper as existing in the Third District some twenty years ago, the writer, as a boy forty years ago, knew to be levees of a fair size and section. They were first located and built upon the banks of a bend, known generally as the crescent of this city, and, from time to time, as caving developed, they were moved back to circumvallate the caves, and, at every recession, owing to the natural slope or lay of the bend, their dimensions necessarily had to be increased. A few years previous to our great high water of 1897, a few of the stretches of levees in this bend passed through an evolution of woodwork construction; the requisite section of earth was superseded by plank, posts and tie rods, and braced to the stone gutter curbs of the Front street. They were called "boxed levees." They were the source of a great deal of worry and uneasiness during the high water of 1897, but by a great deal of work done upon them, principally in rebracing, they withstood the pressure of that high water.

To-day, by the author's advice and recommendation, these stretches of levee have been removed riverward with increased dimensions, part of the section of earthwork is built out on a prepared base of piles 70 to 80 feet long, driven at uniform distances apart, and abbutting a water tight sheet pile bulkhead on the front, with the expectation of replacing this pile bulkhead revetment later on, with a river slope of solid earth, to be supported on a pile foundation,—another stage of evolution. The writer lives in hope that the pile wharf revetment protection work to the bend of the river along the Third District front, the design and execution of the author, will keep these levees from caving off into the river in the next decade or two.

As to the levees on the commercial front in 1717, when they were first built by De La Tour, they were probably "well-banked potato rows," and served the purpose of the limited area they then protected from inundation. To-day a greater part of the commercial front, outside of the original levee line, has been reclaimed to the city by accretions. In this fact we recognize that while the "Father of Waters" is inclined to be bold and bad in many of his ways, giving us a ducking occasionally, and an unkind cut here and there in the bends, yet there is much to be said to his credit, in which the commercial front of New Orleans will bear him out.

From these beginnings in 1717 has evolved the "all-levee system" as it exists to-day, and the writer believes that the portion of it in the delta section of the Lower Mississippi will stand on its own basis and merit. The immediate and most potent motive of its advocates is the reclamation and protection of the alluvial lands of the State bordering on that stream, and the efforts in this direction will not cease until the purpose is accomplished.

Mr. L. W. Brown.—The impression seems to prevail that my paper refers to the Lower Mississippi, as embracing only that portion from the Red River to the Gulf. The arguments relative to increasing floods, their cause and the remedy, as advanced, embrace the river from Cairo to the Gulf; and, as verbally explained to Major Harrod at a previous meeting, the construction of reservoirs, as relief avenues for floods, refers more particularly to that portion from Red River to the Gulf where avenues of escape to sea can be most readily secured. The paper refers to the construction of reservoirs above the Red River, but rather for irrigation than as a relief measure.

The paper records the statement that I am not opposed to levees; and I desire to emphasize the statement so as to positively remove any impression to the contrary, by advising that I consider the levees absolutely necessary; but, as stated in my paper, I consider that levee building, on the lines now adopted, and without the execution of other equally important work in connection therewith, will in a few decades entail disaster to all interests in the alluvial sections, notwithstanding the united opinions of the savants of river and levee matters to the contrary.

I would observe that both Major Richardson and Major Harrod have, in their discussion, studiously avoided any reference to the absolute fact that the levees are enormously higher to-day than two decades ago; and I would further observe that

the levees in 1897 were only by great exertion made to answer their purpose, and that the high and substantial levees which existed in 1897, as compared with the low and weak levees of 1882, offered no greater security against inundation; and as history never fails to repeat, when mankind is inactive, it is not improbable that in 1905, or earlier, the existing levees, which are mountains as compared with those of 1882 or 1897, will be found small and weak, and that protection will require more labor to reinforce and supplement than was required on the levees of 1897, the total cost of which will never be known; but the cost of reinforcement and losses from all causes will probably exceed $100,000,000.

Major Harrod makes use of the following expression:

"The phenomena of any one part are explainable only by a comparative study of all parts where similar conditions prevail."

How could this maxim be applied to the Mississippi River in 1897, when all the parts embraced such phenomenal conditions as produced most disastrous effects, and when there existed no condition by which a comparison of any one part could be made. Hence, there being no means to define the cause of the phenomena of 1897 by comparison of one part of the river with another, the cause is sought to be secured by an inquiry into the effects which the work done by the Mississippi River Commission has produced on the river, by a comparison of the same parts of the river, or of the whole river as refers to some important fundamental element of the river, such as slope, velocity, cross-section, etc., or, if no work had been performed in attempting to improve the river, the same investigation would be necessary to determine what was producing the disturbance, and, when found, to determine to what extent mankind could assist in providing against reoccurrence; and I propose to show, replying to Major Harrod's discussion, that the improvements now being made on the Mississippi River are causing serious interference with one of the fundamental elements of the river,—viz, the slope. With a view of fortifying my conclusions, I will quote a portion of the fourth section of the act of Congress, approved August 29, 1879 (twenty-two years ago), which gave life to the Mississippi River Commission, and which reads as follows:

"SEC. 4. It shall be the duty of said commission to take into consideration and mature such plan or plans and estimates as will correct, permanently locate and deepen the channel and protect the banks of the Mississippi River; improve and give safety and ease to

the navigation thereof; prevent destructive floods, promote and facilitate commerce, trade and the postal service, and when so prepared and matured, to submit to the Secretary of War a full and detailed report of their proceedings and actions, and of such plans, with estimates of the cost thereof, for the purpose aforesaid, to be by him transmitted to Congress."

I refer to the above to show that Congress positively directed that the plans of the commission should embrace the protection of the country against destructive floods, and the instructions are in the most emphatic terms, "It shall be the duty of said commission to mature such plans as will prevent destructive floods." In passing this act, Congress unquestionably realized the importance of the floods of the Mississippi, and that the work of the commission appointed in 1874 to investigate the river, as contained in their report to the Forty-third Congress, second session, embraced the necessary investigation and consideration by eminent hydraulicians to enable the commission appointed in 1879 to proceed with absolute certainty of results; and it is interesting to observe the language of the two acts. The act of 1874 directs that a report shall be made of best methods to protect the alluvial lands against inundation; whereas, the act of 1879 is a positive order to "prevent destructive overflow."

The direct questions may be asked, have the results of the work done by the commission during the past twenty-two years, embracing an expenditure of $35,000,000, carried into effect the direct order of Congress, as issued in 1879? As a matter of fact, has not the expense entailed on the various States, parishes and individuals depending on levees for protection, increased tremendously since 1880, or since the plans of the Mississippi River commission were adopted and partially executed; and does not the rate of increase of cost and height of levees, between 1880 and 1901, very largely exceed the rate for any period of twenty-two years from 1828 to 1880; and have the alluvial districts of the Mississippi been more secure against inundation during the past twenty-two years than they have for any like period prior to 1882; and during the past twenty-two years have not the actual losses from inundation far exceeded those of any like period prior to 1880?

I propose to establish, by the writings, theories and actions of the Mississippi River Commission, that the slope is decreased in proportion as the height of floods are by their own works increased, and will use the recorded and published observations of the commission for evidence.

The following is a quotation from the original report of the Mississippi River Commission to Congress in 1880:

"The bad navigation of the river is produced by the caving and erosion of its banks and the excessive widths with the bars and shoals resulting directly therefrom. It has been observed in the Mississippi River, and is indeed true of all silt-bearing streams flowing through alluvial deposits, that the more nearly the high-river width, or width between the banks, approaches to uniformity, the more nearly uniform will be the channel depth, the less will be the variations of velocity and the less the rate of caving to be expected in concave bends.

"This would seem to be so in the very nature of things, because uniformity of width secured by contraction will produce increased velocity, and therefore increased erosion of the bed at the shoal places, accompanied by corresponding deposit of silt at the deep places.

"Uniform depth, joined to uniform width, that is to say, uniformity of effective cross-section, implies uniform velocity, and this means that there will be no violent eddies and cross-currents, and no great and sudden fluctuations in the silt-transporting power of the current. There will, therefore, be less erosion from oblique currents and eddies, and no formation of shoals and bars produced by silt taken up from one part of the channel and dropped in another.

"As the friction of the bed retards the flow of the water, any diminution of the friction will promote the discharge of the floods. The frictional surface is greater in proportion to volume of discharge where the river is wide and shoal than where it is narrow and deep. It follows, therefore, that after the wide shoal places are suitably narrowed, and the normal sectional area is restored by deepening the channel, the friction will be less than it was before. This will result in a more easy and rapid discharge of the flowing water, and consequently in a lowering of the flood-surface. It would seem, therefore, that the plan of improvement must comprise, as its essential features, the contraction of the waterway of the river to a comparatively uniform width; and the protection of the caving banks.

"INITIAL WORK.

"Under the authority conferred in Section 5 of the act, estimates of cost of certain initial works, constituting a component part of the general system of works contemplated, as submitted.

"These works of channel contraction and bank protection, which in the judgment of this commission, may be advantageously undertaken during the coming fiscal year or as soon as Congress supplies the means, are confined to an aggregate length of 200 miles of the shoalest water below Cairo, embracing the following localities,—namely, New Madrid, Plum Point, Memphis, Helena, Choctaw Bend and Lake Providence."

For good reason, no doubt, although the public is not informed as to that reason, the general plan of contraction of channel and

providing uniform width between banks, uniform cross-section and velocity, as originally determined upon, seems to have been abandoned, and, perhaps for the welfare of our section, it is fortunate that the original plan was not carried out.

It is interesting to note the conclusions of the commission when the inauguration of the work was recommended in 1880. The reports say that the first work "is confined to an aggregate length of 200 miles . . . embracing the following localities,—viz, New Madrid, Helena," etc. All this initial work recommended is located from 600 to 800 miles from the outlet of the river; and all the money expended by the commission for twenty-two years, except some small and spasmodic levee building and useless mattress planting, has been spent in endeavoring to protect the work done by the commission in the upper reaches, in violation of nature's laws, and which would perhaps have been found unnecessary, as the bad conditions in these upper reaches would have corrected themselves had the necessary assistance been provided by improving the outfall; hence a maxim: "To improve the flow or discharge in any stream, improve the outfall and thus increase the slope."

The work done on the Mississippi River during the past twenty-two years is illustrated by a municipality which has a proper and well-proportioned sewerage or drainage system, and in which, as the city grows, considerable expenditure is made in the enlarging and extension of the laterals without any improvement of the main outlet, and experts are called to demonstrate why the system is defective. The main trunk of the Mississippi, between Vicksburg and the sea, is defective, and requires such improvement that the slope will be increased in proportion as the elevation of surface of floods is increased by greater volumes.

The report of the commission, in 1880, contains the following:

"It follows, therefore, that after the wide shoal places are suitably narrowed, and the normal section area is restored . . . this will result in a more rapid discharge of the flowing water and consequently in a lowering of the flood surface."

The above is precisely in line with the recommendation made in my paper; and I contend that the line of levees must be constructed on lines to give the velocity determined as proper in that portion of the river in which they are located; but the inauguration of the work must be at the outfall, and the determination of required velocity at different parts of the river must be decided by the observation and consideration of the conditions secured by the work from the outfall upwards.

Has the commission executed any work, according to the strict interpretation of the first quotation above from their report of 1880? Are they building levees, or recommending them to be built, on the lines suggested by their report? Are they holding caving banks or attempting in any way to maintain the concave sides of bends, which is necessary to carry out their recommendation to secure uniform width, cross-section, velocity, etc.? And does a glance at their reports, or does actual observation, show either that their works of bank protection are stable or that they satisfactorily answer their requirements? As a matter of fact, does the value of the bank protection works which have not washed out and which are now serving any purpose, amount to 10 per cent. of the money expended for their construction? Is it not evident that all the work done by the Mississippi River Commission during the past twenty-two years has been on lines contrary to known hydraulic laws, and is there any reason why the work should not fail? Was it not the proper plan to inaugurate work at the outlet of the Mississippi River and improve the discharge to the sea before attempting to improve the upper trunk and laterals?

The decreasing of slope with increasing flood elevations conclusively proves that hydraulic laws have been violated in connection with the river improvements.

The theory of the plans of the Mississippi River Commission, as generally understood, are that an increased velocity and reduced flood elevations will result from confining the volume, and that any outlet, whether a natural bayou, crevasse or waste weir, would not decrease the flood elevation, except within a few thousand feet of the opening, and would, further, absolutely increase the height of flood slope throughout the river. That the theory, as practiced by the Mississippi River Commission, is an absolute violation of hydraulic laws is shown by the fact that any increase of flood elevation at Cairo or Memphis occasions a flood elevation at Red River and Carrollton, which is very much higher in proportion than such a conclusion would determine proper; in fact, the actual heights, at the several points, above those of preceding seasons of high water, are about the same, or, perhaps, more at the lower end of slope; whereas, with a rise of say 3 feet at Memphis or Helena, the proportional height would be only a few inches at Red River and Carrollton, which proves that the slope is decreased as flood heights increase.

The surface of water of the flood of 1897 was above the surface of water of flood of 1890, at the several points in the river, as follows: Carrollton, 3.07 feet; Red River, 3.53 feet; Vicks-

burg, 3.43 feet; Helena, 4.03 feet; Memphis, 2.06 feet; Cairo, 2.82 feet; which shows that the elevations of floods of 1897, in the lower end of the slope, were much higher above the elevation of flood of 1890 than they were at the upper end, which condition is seen to be reversed from Vicksburg to the sea by comparing the floods of 1890 with the floods of 1874. The height of the floods of 1890, above those of 1874, at the several points on the river, were as follows,—viz, Carrollton, 0.4 foot; Red River, 0.38 foot below; Vicksburg, 3.35 feet; Helena, 1.90 feet; Memphis, 1.60 feet; Cairo, 1.43 feet.

A consideration of the latter table shows that the river is congested between the sea and Vicksburg; while the first table shows that the congested condition extended to Helena, *i.e.*, the water came into these reaches faster than it could be discharged to the sea.

In absence of full slope data, I propose to consider that the gage readings of the Mississippi River Commission supply all requirements for present purposes, and that they are susceptible of reliable deductions as to intensity and variability of slope of floods between points on the river; as, according to the theory of the Mississippi River Commission, the gage readings are not affected by crevasses or other small and local conditions, although Major Harrod, in his discussion, has thought fit to express an opposite view. I will assume that the flood wave extended over a period sufficient to absolutely fill the whole river, as it did in 1897 and in other flood years, and will use the highest gage readings throughout the river for securing a comparative table of slope for different conditions.

The use of gage readings, as I propose, is generally considered proper, and I quote "Seddon on River Hydraulics," where he refers to gages, as follows:

"The gage relations on the Mississippi are not only especially stable, but they are also, in general, especially well-defined single lines; and, in that case, every variation which shows in the surface levels of the same discharge at one of the gages must show in the given ratio and the given period at the other. Changes of plane are transferred as well as discharge curves, and, as far as the gage relations below Arkansas City, each shows a single line for both of these periods, this change of plane is necessarily an identity all the way down."

In the following table Column X is elevation of maximum gage readings above o. C. D.; Column Y the slope between the several points on the river, expressed, in order to avoid fractions, in millimeters per mile. This table embraces the record of ten

seasons between 1874 and 1898, five of which were years of normal floods,—1878, 1885, 1889, 1896, 1898, and the other five are years of high floods,—1874, 1882, 1890, 1893, 1897.

For calculation of slopes, distances are taken as follows:

Cairo to Memphis	230	miles.
Memphis to Helena	76	"
Helena to Greenville	172	"
Greenville to Vicksburg	121	"
Vicksburg to Red River	166	"
Red River to Carrollton	192	"
Carrollton to the Sea	120	"

Years of High Floods.

	Cairo.	Memphis		Helena.		Greenville.		Vicksburg.		Red River.		Carrollton		Sea.	
	X	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1874	338.21	237.97	133	207.80	121	149.20	104	111.74	95	70.90	75	36.61	55	21.26	39
1882	342.71	239.12	135	209.18	120	149.68	105	114.79	88	72.35	78	35.86	58	21.26	37
1890	341.64	239.57	135	209.70	119	151.45	103	115.09	92	72.52	78	37.10	56	21.26	40
1893	340.17	239.17	133	209.90	117	152.30	102	114.34	97	71.57	79	38.36	53	21.26	44
1897	342.46	241.63	132	213.73	117	154.75	104	118.52	91	74.05	81	40.08	54	21.26	48

Years of Normal Floods.

	Cairo.	Memphis.		Helena.		Greenville.		Vicksburg.		Red River.		Carrollton.		Sea.	
	X	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
1878	327.88	233.07	126	200.73	130	146.05	97	106.99	98	63.27	80	32.21	49	21.26	28
1885	329.84	233.22	128	202.68	123	146.05	101	108.44	96	65.81	78	34.46	50	21.26	34
1889	225.37	230.57	126	196.08	138	139.85	97	100.89	98	57.85	79	32.51	40	21.26	29
1896	330.04	232.37	129	200.40	128	142.60	103	105.04	96	61.25	80	34.61	43	21.26	34
1898	340.62	241.56	131	211.09	122	154.16	103	115.44	97	68.15	87	36.81	50	21.26	39

As will be observed, a study of this table is very instructive. The slope from Cairo to Memphis is, in comparison, quite regular, with the several elevations, varying from 126 mm. per mile at elevation 327.88 feet at Cairo in 1878 to 135 mm. at 341.64 feet in 1890, which shows that this stretch of river has a fairly uniform section and that its condition, for discharge of floods, is superior to any of the other sections. It will, however, be noted that the slope in 1897 was 132 mm. per mile and was less than that of any of the other flood years with lower elevations, which would indicate an increasing retrogression of the value of the channel for delivery of floods.

The slope in the stretch between Memphis and Helena has, for floods, gradually decreased from 121 mm. per mile at elevation of 237.97 feet at Memphis in 1874 to 117 mm. per mile with elevation of 241.63 feet in 1897, which shows clearly a decreasing slope with increasing elevation, and that this stretch cannot discharge any large flood with safety. It will be further noted that the slope in this stretch is very much greater under normal floods than in high

floods, the slope in 1878, at elevation of 233.07 feet, being 130 mm. per mile and decreasing with considerable uniformity to 122 mm. per mile at elevation of 241.56 in 1898. It will also be observed that the slope is rapidly decreasing with time for both normal and high floods, which proves that the flow conditions are being interfered with.

The same condition of decreasing slopes with increasing flood elevation is shown to exist in the stretch between Helena and Greenville, where the slope, in 1874, was 104 mm. per mile with elevation of 207.8 at Helena, and it was 104 mm. per mile in 1897 with elevation of 213.73 feet.

In the stretch between Greenville and Vicksburg, the slope in 1897 was only 91 mm. per mile at elevation of 154.75 feet at Greenville, while in 1874 it was 95 mm. per mile at elevation of 149.2 feet, showing a large decrease in slope with increase of elevation of flood surface.

The stretch between Vicksburg and Red River shows a small increase in slope, but not commensurate with the increase in head or flood surface, and between Red River and Carrollton the slope is less in 1897 with elevation of 74.05 at Red River, than in 1874 with elevation of only 70.9 feet, showing a congested condition, retarding velocity and flow.

It is interesting to study the slope from Vicksburg to the sea for the years of 1896, 1897 and 1898, and note the great increase of slope in 1898 over that of 1896, which corroborates my views as expressed in my paper, as follows:

"Why are maximum floods sporadic, seldom, if ever, occurring in yearly succession . . . which clearly demonstrates that the floods with maximum elevations, even with equal volume of discharge, cannot occur in succession, for the reason that the avenues for passage of water are scoured out by the first flood, and the conditions to retard the passage cannot be formed in the interval of time between two flood periods."

And the table above clearly proves that the increasing height of floods is *"due to the increase of resistance for channel to clear itself."*

I fail to understand how the Mississippi River Commission can proceed on the lines now adopted for improving the river. There is so much evidence at hand and so many facts established to prove not only the utter futility of the work, but that it must result in unsatisfactory and disastrous results.

I have proved that increasing floods are decreasing the slope. It is impossible to calculate the ratio, but, assuming that it will

be the same as shown by comparison of 1897 and 1874, the additional height of levee required at Carrollton to contain the floods when the St. Francis Basin is leveed, will be not less than 5 feet.

Seddon, in "Reservoirs and the Control of the Lower Mississippi," refers to the St. Francis Basin as follows:

"Altogether, then, from the evidence of this 1897 flood, there is little doubt that to shut off the outflow completely from all these great basins is to raise the high water stages of such floods from six to eight feet above the level at which the natural reservoir system of this river would have carried them; and even in the interests of a real flood protection alone, it would certainly be wise to consider whether some less dangerous step into the unknown might not be substituted for it."

Starling, on the "Mississippi River," says:

"The St. Francis was closed since 1893 to a distance measured along the river of 120 miles and a gap of 100 miles still remains. It is to the building of these levees and to the maintenance of the lines previously existing that the unparalleled stages attained by the water has been due."

And as for the highly improved alluvial lands below the Red River, the writing of Prof. Lewis M. Haupt is sufficiently suggestive: "The last stage of that property will be worse than the first."

The investigations I have made of the methods now in hand for the improvement of the Mississippi River suggest, as a comparison, an illustration wherein the Mississippi River, from Vicksburg to the sea, represents an old beer keg with the head knocked out, set on end and provided with a rusty, worn-out choked faucet, the key of which has long since been lost; while the river above Vicksburg is represented by a brand new and thoroughly banded whisky barrel set above and arranged to discharge into the old beer keg by two, new highly-polished, non-choking, keyless faucets, and the proprietor of all this outfit is guaranteed by the designer and constructor that, by maintaining the whisky barrel full, the old beer keg might be filled, but would never overflow.

It would appear that, to secure proper and satisfactory results, the work of improving this river must be inaugurated at the sea, the first step being to provide a proper outlet for the ultimate confined volume, and gradually extend the improvement to reach the whole length and breadth of the stream. I am convinced that no levee work, outlet work or jetty work singly will answer the purpose, and that the work must be a combination of several dis-

tinct methods. In this opinion I am fortified by eminent hydraulicians, and will quote as follows:

Herman Haupt on "The Problem of the Mississippi," published in the "Journal of the Franklin Institute," April, 1899, says:

"In May, 1897, the writer published several articles in the New York "Sun" on the Mississippi River problem, the aim of which was to show that of the systems proposed, neither the levee, the outlet, the reservoir, nor any other, singly, would secure protection from overflow, but that a combination of several and an intelligent application of certain recognized principles, with a careful study of local conditions was essential to a practical solution of the problem presented."

This statement indorses the recommendations of my paper. Professor Haupt further says, referring to the known and established variation of slope:

"These variations of slope would necessarily produce variations of velocity, and unless the sediment had been previously deposited every reduction in velocity would cause new deposits in the bed, and every increase in velocity from contraction of the cross-section by levees or otherwise would suspend such deposits, or, in some cases, might even depress the bottom by producing a scour.

"As there are variations of slope and constant contraction and expansion of sectional area, there must necessarily be frequent changes of velocity, and, as a matter of course, there will be deposits in some portions of the bed and none in others, with occasional scour tending to the formation of holes."

This statement is justified by the known results which have their cause verified by the fact that the slope decreases with the increase of elevation of flood; and, referring to the ultimate closing of all the outlets from Cairo to the sea, he has the following to say:

"If the partial closing of the levees in front of some of the basins has resulted in such an enormous increase of flood height that the most elevated levees would have been overtopped and submerged but for the relief afforded by crevasses, what results may be expected when the whole river is confined by continuous levees on both sides? If the volume of water that is poured into the upper portion of the Mississippi is twice as great as is now discharged at its mouth, what must be the elevation of the crest lines of the flood when the volume is doubled? The idea that an increase of velocity will result from the increased volume and, that in consequence, a scour will be produced that will increase depth sufficiently to compensate for increased height of flood has been shown to be fallacious. If there was a continuous scour the material must be deposited somewhere, and the only conceivable place

of deposit would then be at the Gulf, reinforced by all the material brought in from the tributaries and from erosion of the banks, in which case the amount would be so enormous that it would be almost impossible to maintain navigation and New Orleans might become an inland city. Heretofore, relief has been afforded by crevasses and cut-offs, by which it is said that half the volume in flood stages has found its way to the Gulf through swamps, bayous and secondary streams, and was not discharged through the passes. When these avenues of escape are cut off there must necessarily be a great increase in the flood height unless some other mode of relief can be provided.

"The evidence presented should be conclusive that parallel levees of any ordinary height, continuous on both sides of the streams, with outlets all closed, compelling the river to carry and discharge into the Gulf double the former volume of flood water will not, with certainty, secure the country permanently against overflow, but when the limit of the capacity for protection has been attained the danger from crevasses, if they should occur, will be vastly increased."

Prof. J. B. Johnson, before the American Association for the Advancement of Science, in 1884, gave expression to his views, as follows:

"It would seem, therefore, that in the river's present condition, there is no evidence that a confined flood will scour out its bed so as to facilitate the discharge, and there is considerable evidence against it. If the river flowed between straight parallel banks, such as Captain Eads has constructed at the mouth of the river, there then could be no such thing as discontinuous transportation of sediment, and hence no alternate scour and fill. Then concentration of volume would be beneficial and would ultimately lower the river bed. But this condition of things can never be reached on the Mississippi River, and hence the concentration of flood volume will be harmful rather than beneficial."

Seddon, in "Reservoirs and the Control of the Lower Mississippi," invents a very appropriate maxim when he says:

"The idea is a fundamental one that the ills of the river in the main lie in the variations of its flow."

And the question may be asked, has any improvement been made in this main evil during the past twenty-two years? A truthful answer would be that not only has no improvement been made, but that the evil has increased.

The same writer, referring to the partial leveeing of the St. Francis Basin, says:

"This line, as first built, was much too low to withstand the increased flood heights that followed the restricted overflow, and the great flood of 1897, the first that has come against it, broke through the levee in a number of places before it had reached its

extreme by several feet. But it, nevertheless, gave the last and the best indication of what flood heights may be expected when the overflow into this natural reservoir system is entirely closed out."

Major Harrod has seen proper to state that the high water at Carrollton is directly connected with the levee system, and attempts, by a series of averages, to prove that the constantly increasing height of flood waters are merely a natural conclusion and were not unexpected, neither are they higher than was anticipated. These conclusions open up a wide and interesting field for discussion, but for the time, I will refer to them only to make the suggestion that the integrity of levees can be gaged only by that of the weakest part. In this respect the levee is precisely similar to a chain, the weakest link of which represents the maximum strength of the chain; hence, a levee of sufficient integrity to sustain the flood of average elevation would be of no value whatever to sustain the sporadic maximum floods; and, as asked in the former part of this paper, who can foretell, with absolute certainty, what is the future maximum elevation of the floods of the Lower Mississippi? From a careful consideration of the improvements now being made on the river and the results, covering a period of twenty-two years, are we not justified in anticipating that the floods of 1897 will be largely exceeded?

Referring to the question of increased run-off from watersheds from the deforesting of the western slopes of the Alleghenies, it seems to be unsettled, although a preponderance of opinion concludes that the future run-off will not exceed that of the past.

Humphreys and Abbot, on page 437 of their report of 1861, referring to forest, state:

"The removal of the matted undergrowth and the softening of the earth cause a greater quantity of rain to be absorbed, and the exposure to sun increases evaporation."

Seddon makes the following observation:

"Cutting down forests, draining lands, reclaiming swamps, with all the climatic changes that are assumed to go with such development of a country, are each and all given a place in these deductions, and that some of them actually have a place in the flood regimens is possible; but what this is, and what its magnitude, and, indeed, even whether in a given case it would increase or decrease the flood extremes, is in general beyond the range of our present knowledge of the subject."

Referring again to Major Harrod's discussion, we find that he says:

"Abbot demonstrated the futility of attempting to grade up the lower lands of the valley by deposit and overflow."

In the first place, Humphreys and Abbot's deductions and conclusions, while they are generally considered as being very valuable and excellently suited to the conditions of forty years ago, are not to be followed to-day without deep consideration. As a matter of parallel, the rules and deductions governing the use of steam and other engineering specialties, which were considered absolutely perfect forty years ago, are now absolutely obsolete; and it is interesting to note the extreme height of perfection to which all branches of engineering have attained, as compared with forty years ago, excepting only the engineering work in connection with the Mississippi River, which has for forty years made no positive and solid advancement toward providing benefits, either commercially or sanitarily, to the immensely valuable territory tributary thereto; and I do not consider that it is impracticable or impossible to adopt measures which will vastly benefit all interests along the Mississippi River, notwithstanding that Captain Abbot, some forty years ago, concluded otherwise. I further believe that the high attainments of the engineering profession in this country will not allow the Mississippi River to become a bugbear of engineering inconsistencies, reprisals and criticisms, but will insist on the adoption of such enlightened engineering works as will produce results which will be the wonder of the current century.

Major Harrod, in his discussion, says:

"The levee system has received thorough study and full discussion."

I ask, has an opportunity ever been afforded during the past twenty-two years for a discussion of the river matter, and of what use, in the light of the present experience and knowledge, are the discussions of Humphreys and Abbot, and others of forty years ago? Further, is it not a recognized fact that an attempt on the part of any engineer to question the methods now adopted is considered a breach of professional etiquette; and, again, what positive conclusion has the Mississippi River Commission reached on the subject that is accessible to the public? And again I ask, would Barnard, Bailey, Forshey and Eads, were they living to-day, hold the opinion they expressed forty years ago? A quotation from Emerson eminently fits the foregoing:

"With consistency a great soul has nothing to do . . . Speak what you think to-day in words as hard as cannon balls, and to-morrow speak what to-morrow thinks, in hard words again, though it contradicts everything you said to-day."

With candor and satisfaction, worthy of a less interesting and important subject, Major Harrod, in his discussion, says:

" . . . the people who wanted to live and plant in the river States went on strengthening and extending the levees. It is now the adopted system because it is proved thoroughly right and practically useful. Levees have caused no elevation of the bed of the river, no phenomena that were not anticipated, and have developed no insurmountable difficulties. They have at all times been, and they are now, worth every dollar they have cost. So well have those who live behind them been satisfied of this, that there is no relaxation of effort to complete the system."

Each word of the above provides a text, and an instructive and interesting book could be written from this paragraph and entitled "The Candor and Satisfaction of the Mississippi River Commission." I will refer to only a few of the many points this paragraph suggests.

Has the Mississippi River Commission such knowledge, and has it made such investigations as are necessary to determine, with such positiveness as is contained in Major Harrod's language, that the bed of the river is not being elevated? If they have, why is it that this most valuable information is not made public? If the flood elevations are increased, as past experience teaches us they have been, and if they have occasioned a decrease in the slope of the whole river, as is shown to be the case, although not published by the Mississippi River Commission, by what hydraulic laws would the deduction be made that the bed is not fouling? If no phenomenon has occurred which was not anticipated, the Mississippi River Commission is responsible for the losses this country sustained in 1897, amounting to upward of $100,000,000, by not adopting, in 1894, a grade for levees 4 feet above the high water of 1897, instead of adopting this tremendous elevation in 1898; and with the same reasoning, the Mississippi River Commission should at once give us the proper elevation for levees in 1905, so that we can construct them economically.

As to the statement that the people who live behind the levees are satisfied and that they have not relaxed their efforts to raise and enlarge the levees, as necessity demanded, it is most apparent that with them it is "root, hog, or die." Ruin would follow their inactivity; and their wonderful energy in enlarging levees and in fighting the inevitable can be compared only with the achievements of the most enlightened people that occupy the globe to-day.

A casual intruding observation presents itself in the shape of a query as to how much the alluvial lands of the Mississippi

would be improved and enhanced in value to-day if only one-tenth of the money spent on levees during the past twenty-two years had been spent on the improvement of navigation of waterways, roadways, etc.

Major Harrod's remarks relative to reservoirs and the utilization of river sediment for the benefit of mankind are the echo from forty years ago, and will not withstand the intense searchlight investigation of the engineering profession of to-day. The value of the industrial enterprises throughout the alluvial territory is becoming so enormous that we can no longer rest satisfied with antiquated opinions or be governed by laws long known to be obsolete; and the engineering profession, in the very near future, will provide a way to secure to mankind the benefits which nature intended should be imparted through the medium of the greatest drain in the world, in like manner as this same profession has unlocked nature's storehouse of coal, iron and other commodities now so necessary for our existence.

Referring to Major Richardson's discussion, I must content myself with referring to only the last two paragraphs, as the introduction of Mark Twain as a competent river expert, and quoting him as an authority, places the subject beyond my ability to discuss it.

Considering the intense moment of the subject under discussion, the immense interests involved and the prominent position occupied by Major Richardson, together with his favorably known characteristics, and the extent of his experience, I am greatly surprised that he should choose to consider the matter in so careless a light and treat it with so much irony and levity.

Major Richardson, in concluding his discussion, makes a statement which is entitled to be classed as famous, which in substance is that the elevations for grade of levees, as fixed by Humphreys and Abbot forty years ago, was practically approved and adopted by the commission in 1874, and by the Mississippi River Commission, that no flood had come within 1 foot of some mysterious grade fixed by the Mississippi River Commission at Carrollton, and that only one flood has reached the mark set by Humphreys and Abbot, forty years ago.

Referring to page 441 of Humphreys and Abbot's report, we find the following, relative to proper heights for levees:

"To secure this end in the most economical manner, the operations of this survey indicate that levees should be constructed. Near the mouth of the Ohio, they should be made about 3 feet above the actual high-water level of 1858 . . . Between that

locality and Baton Rouge, it should be kept uniformly about 4 feet, and below Baton Rouge about 3 feet. If the water-mark of 1858 be unknown at any locality, it may be reduced to any well-determined local mark by the table in Chapter II . . . It should be remarked that these heights are based upon the supposition of *absolute security*."

Now understand, clearly, that these heights refer to the top of levee above the surface of the high water of 1858, to provide "*absolute security*" against inundation. The elevation of the high water at Cairo in 1858 was 49.56 feet and the top of levees, as recommended, 52.56 feet. The high water of February, 1883, was 52.17 feet, which made the top of levees as recommended by Humphreys and Abbot only 6 inches out of the water. The surface of the high water at Carrollton in 1858 was 15.1 feet, and the top of levees, as recommended, 18.1 feet. The high water of 1897 was 19.17 foot, or 1.07 foot above the top of such levee.

Supplementing with facts from recent history, I would state that, succeeding the high water of 1874, the City Council, who then had charge of the levees throughout this city, fixed the elevation of the top of levees 3 feet above the high water of 1874, or at 18.7 feet. In 1890 Major B. M. Harrod, member of the Mississippi River Commission, then city engineer and consulting engineer of the Orleans Levee Board, fixed a grade for the construction of wharves and landings along the city front at 18.6 feet, and no doubt recommended that this elevation would satisfy all future needs. Succeeding the flood of 1897, the Orleans Levee Board fixed the grade of levees throughout the Parish of Orleans, excepting the commercial front, at 4 feet above the high water of 1897, or at 22.17 feet at Carrollton, which is 5.07 feet higher than the elevation of the top of levee as fixed by Humphreys and Abbot, forty years ago.

Referring to the concluding paragraph of Major Richardson's discussion, wherein he expresses satisfaction with the deductions and conclusions of the investigation made by Humphreys and Abbott, forty years ago, and those of the Mississippi River Commission, I can but express my astonishment, considering the experience of the past ten years, that an engineer of his attainment and his experience would be satisfied with any past conclusions, and that he is not among the first to advocate measures looking toward relieving a people who have the record of being the highest taxed and the poorest protected of any people in America, and whose ability to exist is accounted for only by the enormous fertility of the country.

That the engineering profession makes not only wealthy individuals, corporations and nations is no canard, although the public fails to recognize such distinction; and this fact has been very gracefully presented to the world by the address of Past President Wallace at the meeting of the American Society of Civil Engineers at London, England, in July, 1900, as also by Past President Malochee of the Louisville Engineering Society. With such a merited honor, and with such responsibilities, can the profession allow the Mississippi River to be continually menacing, with disaster and destruction, a most valuable country, which is susceptible of extraordinary growth, resulting in great wealth, and is it not incumbent on the Louisiana Engineering Society, whose members, owing to their location, are most in touch with the interests to be served, to inaugurate and pursue a vigorous and unbending policy until success is achieved, and thus maintain the prestige of the profession, receive the encomium of a grateful people and secure the satisfaction of having accomplished that which well served our time and generation?

OBITUARY.

David Walker Hardenbrook.

MEMBER, MONTANA SOCIETY OF ENGINEERS.

IN the death of David Walker Hardenbrook, the Montana Society of Engineers lost a member of whom it may be said that he was truly a product of Montana, as he was born in the town of Deer Lodge, on March 1, 1869, and received his education and spent the greater part of his life within the boundaries of the State. Most of his earlier years were spent upon the ranch, and his education necessarily started in the country school-house.

In 1885 he began the preparatory course in the College of Montana, at Deer Lodge, Mont. He entered the freshman year of the course in mining engineering in the fall of 1887, and received his degree in June, 1892.

He began his life's work under Mr. F. W. C. Whyte, a member of this Society, and at that time chief engineer of the Butte, Anaconda and Pacific Railway, then in process of construction. His service with this company extended through many of the branches of the work. He was draftsman in the chief engineer's office for some time, and later he took up the field work in various branches as topographer, level-man, transit-man and finally as engineer in charge of construction.

Three years were spent in the employ of this company, and the following two years in miscellaneous engineering work throughout the State, mostly in public land surveying under Mr. H. B. Davis, of Deer Lodge, and later with Messrs. Sizer & Keerl, of Helena.

Later he became associated with Mr. Chester B. Davis, the eminent hydraulic engineer, during the time that gentleman was gathering data concerning the water supply in the vicinity of Anaconda, Mont.

About this time, during the summer of the year 1897, he was asked to go to Mexico, as assistant engineer for the American Mining Company, at El Oro, under a contract for two years, and his acceptance of this invitation marked a turning point in his life, as the hardships he there endured laid the foundation for the disease which finally resulted in his death.

He took up his work in Mexico under trying conditions, being put in charge of a party on railroad location, all of whom were native peons, and only one of whom could speak English and had been on work of that kind before.

The fact that Mr. Hardenbrook did not know a word of Spanish was also against him, but he went at the job with de-

termination; and with the aid of the assistant whom I have mentioned, he mastered a little Spanish and successfully carried on his work.

About this time he was stricken with typhoid fever and spent two months in a hospital in the City of Mexico.

Upon his recovery he returned to his work, but in a short time was obliged to go into the hospital again, owing to a throat trouble, probably an after-effect of his first illness.

Two months were spent in an effort to get well, and though he worked the balance of his time, his health was much broken.

His two years being up, he returned to Montana in June, 1899, coming by way of Vera Cruz, sailing thence to Havana, Cuba, and on to New York, and returning thence by rail to Montana, visiting many of the larger cities on the way.

He became an employe of Messrs. Harper & Macdonald, civil and mining engineers, at Butte, Mont., and later was with the Montana Ore Purchasing Company, in the engineering department.

He finally accepted a position under Mr. F. S. Jones, chief engineer, B. A. & P. Ry., as resident engineer, located at Anaconda, Mont. His health was failing rapidly at this time, and after a few months in this last position he was compelled to resign, and upon the advice of friends went to California in search of renewal of his former vigor and strength. But it was not to be, and, after lingering some time, he passed away on February 24, 1901.

David Walker Hardenbrook was somewhat backward in his demeanor, and perhaps slow in gathering friends, but he never lost a friend once made.

As a tribute to his worth as a man, and to his ability as an engineer, Mr. F. S. Sizer, the President of this Society, at present sojourning in Mexico recently writes: "I have just learned of the death of Walker Hardenbrook and wish to join you and other friends in mourning his loss. I know that those members of our Society who enjoyed his personal acquaintance will feel as I do, that the highest tribute of praise to his character and life cannot do more than simple justice to his worth. He was singularly upright and honest and of more than average ability, being especially adaptable to difficult conditions as they arose in his professional work. During one summer, I think about six years ago, he was in my employ, and a more faithful assistant I never knew. Since then I have come in contact with him in Butte, and predicted for him a notable career."

Association of Engineering Societies.

Vol. XXVI. JUNE, 1901. No. 6

PROCEEDINGS.

Engineers' Club of St. Louis.

528th Meeting, June 5, 1901.—Held at 1600 Locust street; Vice-President Kinealy presiding.

Attendance, twenty-four members and ten visitors.

Upon motion being duly carried, the reading of the minutes of the 527th meeting was dispensed with, as the same had been printed and circulated among the members.

The doings of the 311th meeting of the executive committee were reported.

The application for membership of Mr. John I. Boggs was read. Messrs. Hans C. Toensfeldt and Arthur Tappan North were elected to membership.

The subject of the evening was a paper by Mr. A. H. Blaisdell, entitled "The Western River Steamboat."

Mr. Blaisdell exhibited about fifty lantern slides prepared by himself from photographs of boats and drawings, detailed some tests of steamboat performances, illustrated the path of the paddle wheel and its slip, gave examples of speed calculations and outlined the method of designing a steel hull, with calculations of stability, strength, etc.

The discussion was participated in by Messrs. Flad, Bryan and others.

Adjourned to library room where justice was done to a light lunch provided by the entertainment committee.

Adjourned until September 18, when Mr. J. A. Ockerson will present a paper entitled "The Mississippi River: Physical Characteristics and Methods of Improvement."

W. G. Brenneke, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, June 7, 1901.—Called to order at 8.30 p.m. by the President, Prof. C. D. Marx.

The minutes of the last regular meeting were read and approved.

Mr. Harry A. Noble, with Board of Public Works, San Francisco, who had been proposed at the last meeting by F. C. Herrmann, Hermann Kower, C. E. Grunsky and Luther Wagoner, was declared duly elected a resident member of the Society upon count of ballots.

The proposition of Mr. James Spiers, Jr., to become a member, indorsed by Luther Wagoner, C. D. Marx, E. F. Haas and Adolf Lietz, was ordered to ballot, it having been duly approved by the Board of Directors.

Mr. W. H. Smyth, consulting engineer of San Francisco, and Mr. Franklin Riffle, civil engineer of San Francisco, were reinstated to full membership in the Society, upon due approval by the directors.

The death of Mr. B. T. Lacy, member Technical Society, was announced, and the following committee notified through the Board of Directors to draw up a suitable resolution in memory of the deceased member: Mr. John Richards, Mr. Geo. W. Dickie and Mr. Geo. E. Dow.

Mr. John Richards then read the paper of the evening, entitled "Industries of the Upper Rhine," based upon personal observations made during a recent European visit.

The subject was discussed by Mr. Geo. W. Dickie.

Meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of Cincinnati.

124TH REGULAR MEETING (POSTPONED), CINCINNATI, OHIO, MAY 23, 1901. —Dinner was served at 6.15 P.M.

The regular meeting was called to order at 7.15 P.M. with President Jewett in the chair, and eleven members present.

Minutes of the meeting of April 18 were read and approved.

The question announced for discussion, "What Can be Done to Increase the Usefulness of the Cincinnati Engineers' Club?" was taken up, several members making suggestions that the members themselves take more interest in the affairs of the Club, by a more regular attendance at the meetings, and by the preparation of papers and questions for discussion, inviting engineers not members to attend the meetings and join the Club; that the Club interest itself in public matters of an engineering nature, by expressing itself when questions of engineering construction or the employment of engineering talent on public works are proposed.

In this connection the Secretary read a letter addressed to the President from Mr. John C. Trautwine, Jr., Secretary of the Association of Engineering Societies, offering to assist in any way that he could to advance the usefulness or increase the attendance and membership of the Club.

The President announced the death, which occurred on May 14, of Alfred Petry, one of the charter members of the Club, and one who always took an active interest in its affairs. On motion that the President appoint a committee to prepare a suitable memoir, the following were announced as such committee: Messrs. Jewett, Devenish and Wilson.

Mr. James A. Stewart read the paper for the evening, on the subject, "A Plan to Utilize Unemployed Labor," being a suggestion for a plan by which men in the various trades with scant employment during the dull winter months, as well as dealers in materials, were to be employed in the construction of buildings, etc., under an arrangement by which they were to give their labor and materials, receiving therefor a certain proportion of its value and retaining an interest for the balance in an organization somewhat on the plan of a Building Association. Discussion by Messrs. Wulff, Devenish, Jewett, Fritsch, Pfister, Bogen, McAvoy (visitor) and Punshon.

On motion, a vote of thanks was extended to Mr. Stewart for his paper.

Adjourned.

J. F. WILSON, *Secretary.*

Association of Engineering Societies.

Vol. XXVI. JANUARY, 1901. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

516th Meeting, December 5, 1900.—The meeting was called to order at 8 o'clock; with President Chaplin in the chair. Thirty-five members and six visitors were present. The minutes of the 515th meeting were read and approved. The minutes of the 300th meeting of the Executive Committee were read.

The applications for membership of Messrs. Wilbur Hayes Thompson and George Dyer Johnson were presented to the Club.

The annual reports of the Executive Committee and Secretary were read, and on motions duly seconded were received and filed. The Treasurer's report was read and referred to the Executive Committee. The report of the Board of Managers was received and filed. It contained detailed statistics of the Association of Engineering Societies prepared by the General Secretary, Mr. John C. Trautwine, Jr. The local board recommended the adoption of resolutions by which it might be possible to secure advertisements for the Journal of the Association of Engineering Societies, and in this way increase the general fund of the Club. The commissions for securing such advertisements were to be paid from the general fund as provided for in the plans submitted by the Board of Managers. Upon being amended the resolutions were duly seconded and carried. The amendment provides that after the plan devised by the local Board of Managers is submitted to the Executive Committee for approval and passed, it be also presented to the Club for final action.

The report of the Entertainment Committee was received and filed.

The Librarian's report was read and filed. The library during the past year had received considerable attention, a large number of books having been added and a most convenient card-index system adopted.

It was moved and seconded, and the motion carried, that the arrangements for the annual dinner be left to the Executive Committee.

The Nominating Committee made its report with the following nominations:

For President—E. J. Spencer.

For Vice-President—J. Pitzman.

For Secretary—William G. Brenneke.

For Treasurer—George I. Bouton.

Librarian—J. L. Van Ornum.

Directors—A. H. Blaisdell, E. E. Wall.

Board of Managers—W. A. Layman, S. E. Freeman.

Additional nominations were made for office of Vice-President,—viz, William Bouton and J. H. Kinealy.

Mr. William Bouton read a short paper on the "Probable Error per Tape Length in Surveyor's Field Work." A discussion was given of the errors arising from measurements in surveyors' field work, a distinction being made between the error per tape length and that per unit length. The discussion was participated in by Messrs. Pitzman, J. L. Van Ornum, B. H. Colby, Robert Moore and E. A. Hermann.

Adjourned to adjoining room, where a light lunch was served.

F. E. Bausch, *Secretary.*

517th Meeting, December 19, 1900.—The annual dinner of the Club was held at the St. Nicholas Hotel at 7.30 P.M.; with President W. S. Chaplin in the chair at the head of the table. Thirty-nine members and one visitor were present. After the dinner was over the result of the letter ballot for officers for the new year was announced as follows:

President—E. J. Spencer.

Vice-President—No election; none of the three candidates receiving a majority.

Secretary—William G. Brenneke.

Treasurer—George I. Bouton.

Directors—A. H. Blaisdell, E. E. Wall.

Members of Board of Managers—W. A. Layman, S. E. Freeman.

As Mr. Pitzman requested the withdrawal of his name as candidate for election to Vice-Presidency, the contest for office lay between the two remaining nominees. A new ballot was taken, resulting in the election of J. H. Kinealy.

Mr. Chaplin, as retiring president, offered some timely suggestions. The engineer, due to his superior education, should take a greater interest in the guidance of public affairs. He should be regarded as authority on all matters pertaining to public improvements.

Mr. Chaplin surrendered the chair to Mr. E. J. Spencer, who presided the rest of the evening. Mr. Spencer alluded to the high character of the Engineers' Club, and its important work in general.

Mr. A. L. Johnson spoke on "What Are We Here For?" He was of the opinion that the Club as a unit might exert its influence on subjects of public importance. In reply to this, one of the members referred to the action of the Club on the filtration question, the results of which are fresh in the minds of all Club members.

Mr. Robert E. McMath spoke on "Little Given, but Much Required." He alluded to the great work of city improvements carried on with practically no funds at hand. His remarks were of great interest, as they dealt with home institutions.

In the absence of Mr. H. H. Humphrey, who was sick, the Chair invited Prof. F. Spalding, of the State University, Columbia, Mo., to make a few remarks. He spoke on the "practical and impractical" side of engineering. Reference was made to the advantages of belonging to an engineers' club, where the practical ideas of engineers are discussed.

Prof. J. L. Van Ornum spoke entertainingly on "Solar Walks of Engineering."

Following the above, short speeches were made by Messrs. Nipher and Ockerson.

A motion was made and duly carried that a vote of thanks be tendered the past officers. A unanimous vote was cast, members rising.

Meeting adjourned.

F. E. Bausch, *Secretary.*

518th Meeting.—Held at 1600 Lucas Place, January 2, 1901, 8.15 p.m.; Col. E. J. Spencer presiding. Twenty-two members and seven visitors were present.

The Secretary reported the minutes of the 516th and 517th meetings were not ready for presentation to the Club, and requested that reading of them be postponed until the next meeting. The request was granted.

Minutes of the 301st and 302d meetings of the Executive Committee were read, but no action was taken upon them, as they had not been approved by the Executive Committee.

The following candidates for membership were balloted on and declared unanimously elected, viz: Wilbur Hayes Thompson, George Dyer Johnson.

The application for membership of Edward C. Dicke and William C. Zelle were read and referred to the Executive Committee.

A communication was read announcing the death, on May 29, 1900, of Mr. A. J. Sypher, non-resident member, of Millerstown, Pa.

The announced subject for the evening was a paper by Prof. J. L. Van Ornum, on "Purification of Sewage by the Septic Process."

As the Club was honored by the presence of Prof. Emery S. Johnson, Professor of Commerce and Transportation, University of Pennsylvania, and member of the United States Isthmian Canal Commission, a departure from the announced subject of the evening was made, and Professor Johnson was invited to speak on the work of the Isthmian Canal Commission. The speaker is chairman of the committee appointed to investigate the commercial features of the Isthmian Canal, but did not discuss those features, his remarks being limited to the engineering problems only. The speaker's talk was informal, but he presented in a quite brief but very instructive and entertaining manner the results of the work of the commission in investigating the subjects of the construction of the Isthmian Canal, by and under the control of the United States Government, across Central America.

The speaker began with a short historical review of previous investigations and attempts at a solution of the problem, and then explained that three routes had received the chief study of the commission:

(1) A possible route across the Isthmus of Darien.

(2) The route through the State of Panama, traversing Lake Bohio, recommended and adopted by the French, and

(3) The route through the States of Nicaragua and Costa Rica, traversing Lake Nicaragua, and known as the Nicaragua route.

From the purely engineering standpoint, the Darien route seemed inferior to both others, owing to the fact that in order to construct a tide level canal a great tunnel would have to be constructed, and for a high level canal it did not lend itself as readily as the other routes. The commission considered a tunnel in a canal more objectionable than one or more locks.

Of the remaining two routes, the Panama seemed the more practicable as regards engineering features, but the undesirability of the concessions it was considered possible to secure led the commission to recommend the Nicaragua route.

The latter route will require the construction of a large masonry dam across the San Juan River, the construction of a harbor at each end of the canal, the building of a number of miles of artificial canal and the improvement of existing waterways. The controlling factor in the time required to construct the canal is the construction of the dam. It has been estimated this would require about eight years' time (possibly only six), and that the entire canal could be finished in this time without unnecessary duplication of plant.

The estimated cost of the canal is about $200,000,000.

A discussion then followed, bringing out a number of interesting points. The discussion was participated in by Messrs. Pitzman, Bryan, Colby and Grimm.

The President, on behalf of the Club, then thanked Professor Johnson for his very interesting talk.

The Chair then asked the late Committee on Entertainment to provide a lunch for the next meeting.

Adjourned at 10 P.M. W. G. BRENNEKE, *Secretary.*

519TH MEETING JANUARY 16, 1901.—Held at 1600 Lucas Place, 8.30 P.M.; President Spencer presiding.

Minutes of the 516th, 517th and 518th meetings were read and were approved with corrections.

Minutes of the 301st, 302d and 303d meetings of the Executive Committee were read.

The Secretary, who had been appointed by the Executive Committee to act in conjunction with the Treasurer, in auditing the accounts of the retiring Treasurer, reported the accounts correct.

The Committee on Annual Dinner reported a deficit of $18, and motion was carried to appropriate this amount from the Club's funds to cancel the indebtedness.

Notice was given that those members desiring the report of the Nicaragua Canal Commission (not the Isthmian Canal Commission) could obtain the same by communicating with Rear-Admiral Walker, Washington, D. C.

Letters were read from the President of the Society of Civil Engineers of France to the President, and to Mr. J. A. Ockerson, the Club's representative at the convention of the French Society last summer. These letters conveyed an expression of sympathy and an assurance of the continuation of the friendly relations now existing between the two societies.

A pamphlet containing the reports of the receptions given by the French Society during the period of the Paris Exposition of 1900, in which the Club's delegate, Mr. Ockerson, participated, was received.

Mr. Ockerson donated to the Club a book on the manufacture and use of cements, which is a prospectus of the "Societe Ginirala et Unique des Ciments de la Porte e France."

The death of Mr. J. M. Desloge on September 17, 1900, was announced.

Mr. Edward C. Dicke and Mr. William C. Zelle were unanimously elected to membership.

The subject of the evening was a paper by Prof. J. L. Van Ornum, entitled "The Purification of Sewage by the Septic Process." Professor Van Ornum first reviewed the development of the septic process, in practice and in theory, and then discussed the problems needing further study and how such investigations might be made. He considered the system beyond the experimental stage and that it had been thoroughly tried and proven a success. The author expected that as the application of established principles is perfected and further investigations are made its efficiency will become still greater and its field of application be extended.

Discussion of the paper was participated in by Messrs. Russell and A. L. Johnson.

The Chair asked for report from the Committee on Monument to James B. Eads. Mr. Ockerson reported that as far as he knew no meeting had been held by the committee during the past year.

There was no report from the Committee on Smoke Prevention, all of the members of that committee being absent.

The Chair announced the appointment of the following Entertainment Committee: H. H. Humphrey, Chairman; D. W. Roper, W. H. Reeves.

Adjourned to another room, where lunch was served.

W. G. Brenneke, *Secretary.*

Engineers' Society of Western New York.

Regular Meeting, January 2, 1901.—Meeting called to order by the President at 8.30 p.m. The following members present: Messrs. Haven, Norton, Vanderhoek, Knapp, Roberts, C. F. Morse and Weston; also visitor H. C. Booz.

The minutes of the last regular meeting were approved as printed.

The President said, "By your ballots you have elected, as members, Jasper S. Youngs, John T. Herron, John J. Clahan, Charles S. Boardman, Henry Clark, Harry Bartlett Alverson, Frank L. Bapst, and as associates, Emmett W. Huntington, Charles Mosier, Louis Marburg." Applications for membership from David A. Decrow and Horace C. Booz as members, James Franklin, George E. Marsh, Mathew S. Gardiner and Raymond J. Ryan as juniors, Samuel J. Dark, Albert William Caines and William Franklin, Jr., as associates, were received, approved and ordered to letter ballot.

A letter from Mr. T. Guilford Smith, Director of the Society since its organization, relating to fuller information being necessary on letter ballots was read, and the attention of all Committees on Membership was called to the matter, and they were requested to see to it that fuller information was given in the applications.

The President called the attention of the Society to the necessity of the members attending the meetings and talking on subjects of current interest relating to their professions in Western New York. He remarked that it made no difference what measures should be adopted by the Executive Board or the officers so long as the members did not appear at the meetings and talk on these subjects, and that many engineers are disappointed that their profession is not recognized as a force in the community the same as the lawyers and other professional men, but this is very much owing to themselves in that they keep their knowledge hid under their own craniums.

Until they come to the meetings and talk on subjects of current interest to the public of Western New York, and have such discussions published, they cannot expect to be recognized as having any knowledge of value to the public. During the last six months two docks have failed from overloading, in both cases involving loss of human life, and yet not one word has appeared in the public newspapers from the engineers of Buffalo in regard to the cause of these disasters, nor any suggestion that they know how to construct a proper dock. Attention was called to several other public works about which the members of this Society have been silent.

On motion of Mr. Vanderhoek, seconded by Mr. Norton, it was voted that the President and the Executive Board be authorized to appoint committees to furnish topics for discussion on any subject that may be suggested.

The President then asked the members present to suggest topics, and the names of the men for such committees. The President then appointed committees of the Society as follows:

Past-President George A. Ricker, on Docks.

John T. Herron, on Gas.

Thomas W. Wilson, on Modern Street Railroads.

Edward B. Guthrie, on the Engineering Exhibit at the Paris Exposition.

Major Thomas W. Symons, on Niagara River Regulation.

George H. Norton, on Buffalo River Cut-offs.

The President was requested to write to several other gentlemen not now members of the Society, asking them to address the Society on several subjects,—namely, "Concrete Construction," "Goat Island Bridge," "Engineering Features of the Steel Plant."

Meeting adjourned at 10 P.M. G. C. DIEHL, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, JANUARY 4, 1901.—Called to o. der at 8.30 P.M. by Vice-President Falkenau, who announced officially the death of the honored President of the Society, Mr. George W. Percy, and in a few words spoke of the many virtues of the man who for the past two years had been the head of the organization, and whose sudden loss came as a great shock to those who had been constantly in contact with him.

The members rose in honor to the memory of the late President.

The minutes of the last regular meeting were read and approved. The following gentlemen were elected to membership in the Society, having received the requisite number of votes: Members, Norman B. Livermore, civil engineer, San Francisco; Harris D. Connick, civil engineer, San Francisco; John J. Hollister, civil engineer, Santa Barbara; Charles M. Kurtz, civil engineer, San Francisco; Perry F. Brown, civil engineer, San Francisco.

The Nominating Committee, through its Chairman, Mr. C. E. Grunsky, made a report, placing in nomination the following members to fill the offices of the Society for the year 1901:

For President—Prof. C. D. Marx.

For Vice-President—D. C. Henny.

For Secretary—Otto von Geldern.

For Treasurer—Edward T. Schild.

For Directors—Edward F. Haas, Samuel C. Irving, Adolf Lietz, Paul W. Prutzman, Luther Wagoner.

The report was ordered received, and the Secretary instructed to prepare the ballots for the annual election, to be held January 18, the Chair appointing as tellers for the occasion Charles M. Kurtz and Perry F. Brown.

A memoir in honor of the late President G. W. Percy was read by Mr. G. A. Wright, who had been appointed for this duty by the Vice-President at the previous directors' meeting.

The memoir was ordered received and spread in full upon the minutes; also to be published in the JOURNAL OF THE ASSOCIATION, with an additional number of extra copies to be printed for the family and friends of the deceased.

Major Charles E. L. B. Davis read a paper in discussion of the subject placed before the Society at the meeting of December by Mr. George W. Dickie, entitled "The Need of Education of the Judgment in Dealing with Technical Matters."

Major Davis's statements led to further discussion of the interesting subject, which was participated in by Messrs. Vischer, Wright, Wagoner and others.

Adjourned. OTTO VON GELDERN, *Secretary.*

DIRECTORS' MEETING, JANUARY 26, 1901.—Called to order at 4 P.M. by President Marx. Present, Directors Marx, Prutzman, Lietz, Schild and von Geldern.

The Chair appointed the following Committees: Executive—Messrs. Wagoner, Prutzman and Haas. Finance—Messrs. Lietz, Irving and Schild. Members on the Board of Management, Associati n of Engineering Societies—D. C. Henny and Otto von Geldern.

After approving the proposition of the Secretary to invite Mr. Charles Burckhalter to deliver an address before the Society on his results of photographing the solar corona at Siloam, in May, 1900, the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of Cincinnati.

13TH ANNUAL MEETING, CINCINNATI, OHIO, DECEMBER 20, 1900.—Dinner was served at 6.30 P.M. The regular meeting was called to order at 8 P.M.; President Punshon in the chair. Twenty members present.

Minutes of the meeting of November 15 were read and approved.

Applications for membership were presented as follows:

Guy M. Gest, general contractor, 90 Perin Building, Cincinnati, for associate membership.

R. J. Bevenish, assistant engineer, Board of Trustees, Commissioners of Water Works, California, for active membership.

John P. Brooks, Professor of Civil Engineering, State College of Kentucky, Lexington, Ky., for active membership.

On ballot being taken Mr. James C. Hobart was elected an active member.

The letter from Professor Diemer, presented at the last meeting, in reference to the establishment of a Department of Mechanical Engineering at the

University of Cincinnati, was taken up, and after some discussion was referred to Messrs. Bogen and Baldwin for report as to the advisability of the Club taking any action in the mattter.

The reports of the Secretary and Treasurer for the year 1900 were presented, ordered received and filed and printed, together with a revised list of members for distribution.

The report of the Secretary shows that the attendance has fallen off from 18 in 1899 to 16.3 in 1900; that the membership has also fallen off from 97 at the end of 1899 to 88 at the end of 1900. There were 5 new members elected during the year, 1 death, 9 resignations and 4 members dropped for non-payment of dues.

The Treasurer's report shows receipts amounting to $662.50, disbursements $614.85 and a balance on hand of $343.60.

Officers for the year 1901 were elected as follows:

President—William C. Jewett.

Vice-President—Louis E. Bogen.

Directors—A. O. Elzner, C. N. Miller, H. E. Warrington.

Secretary and Treasurer—J. F. Wilson.

The following question was found in the question box: "What do you consider the maximum resistance per square foot for ordinary clay soils such as are found in the vicinity of Cincinnati, when designing foundations for bridges and buildings? Why?"

This was discussed at some length, it being the general opinion that while the soils at different localities would sustain different weights, one to two tons was about right, although in cases more than that had been allowed.

Upon the newly-elected President taking the chair the retiring President read the paper for the evening, as has been the custom, taking for his topic the question of parks for Cincinnati, which he treated in a very able manner.

On motion, the Club adjourned after extending to the retiring President a vote of thanks for his paper, and for the interest and work in behalf of the Club during the past year.

J. F. WILSON, *Secretary.*

Louisiana Engineering Society.

NEW ORLEANS, JANUARY 12, 1901.—The annual meeting of the Louisiana Engineering Society was called to order this date at 8 o'clock P.M. by President Malochée; twenty-five members and four guests being present.

The minutes of the meeting, held December 10, and the adjourned meeting, held December 17, were read and approved. Also, the minutes of the Board of Directors' meetings held on December 29, January 5 and January 15, respectively, were read for the information of the members present.

The annual report of the Board of Direction transmitting the reports of the Secretary, Treasurer and the three standing committees was read and approved.

A communication from Mr. John P. Coffin, Vice-President of the Southern Industrial Association, was read, which invited the Louisiana Engineering Society to join the association as a corporation. This was indorsed by the Board of Direction with the recommendation that the Society join said In-

dustrial Association. The communication was received, and it was decided by vote that the Society would join, and the Secretary was instructed to issue warrant for $10, being the amount required for the annual dues.

The ballots for officers of the Society for the year 1901 were opened; Messrs. Duval, Wright and Lombard being appointed by the President as tellers. After a short recess, during which the votes were being counted, the Chair announced that fifty-one votes were cast, and the following gentlemen were elected to the several offices:

President—F. M. Kerr.

Vice-President—J. F. Coleman.

Secretary—John F. Richardson.

Treasurer—Walter H. Hoffman.

Director—Alfred Raymond.

Member Board of Administrators of the Association of Engineering Societies—H. J. Malochée.

An able and eloquent address was then delivered by Mr. H. J. Malochée, the retiring President. His subject was a review of the important office the modern engineer is performing in the economy of the world, and the duties and the importance of the position occupied by the engineering societies as factors in keeping up and raising the code of professional ethics among engineers.

A vote of hearty thanks for the preparation of his masterly paper and for the conscientious and successful manner in which he and his brother officers had conducted the affairs of the Society during the past year was given to Mr. Malochée.

Mr. F. M. Kerr, the new President, was installed in the chair, and made a brief speech of acceptance.

It was announced that the next regular meeting would be held on Monday, February 11.

The meeting adjourned at 10.05 P.M.

GERVAIS LOMBARD, *Secretary.*

Association of Engineering Societies.

Vol. XXVI. **FEBRUARY, 1901.** No. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

520TH MEETING, FEBRUARY 6, 1901.—Held at 1600 Lucas Place, 8.30 P.M.; President Spencer presiding. Thirty members and fourteen visitors were present.

Minutes of the 519th meeting were read and approved.

Minutes of the 314th meeting of the Executive Committee were read.

The applications for membership of Messrs. W. H. Henby and Truman M. Post were read.

President Spencer presented a draft of an "Act prohibiting the discharge of dense black smoke from any premises within the limits of all cities of the State of Missouri having a population of three hundred thousand inhabitants." This, together with a memorial to the General Assembly, was offered by the Chairman of the Committee on Smoke Prevention, with the suggestion that the members of the Club sign the same.

Upon discussion, it developed that Mr. Moore, Chairman of the Smoke Prevention Committee, preferred to have the memorial signed in the name of the Club by its officers. Upon motion made and duly seconded, it was ordered that the President sign and the Secretary attest the memorial.

Mr. D. W. Roper, who had taken up matter of repairing lantern, reported that same had been repaired and the lantern was in shape to exhibit, although it was far from perfect.

Motion made and carried, the Chairman appointed committee of three to report to the Club on lantern, stating what steps must be taken to secure a lantern which will give the best results. The committee appointed was Mr. Flad, Chairman, Mr. Roper and Mr. Maltby. This committee was also ordered to look up the matter of obtaining a good reading lamp for service in the meeting room.

The subject for the evening was an informal address by Mr. Arthur Thacher, president of the Central Lead Company and the Renault Lead Company, on "Lead Mines in Missouri." The speaker discussed, in a very interesting manner, but in a general way only, the geological features of the three lead districts of this State, taking up separately the Southwest

Missouri district, the Central Missouri district and the Southeast Missouri district.

Particular attention was given to the mines of the latter district, as they produce by far the greater proportion of the lead of the State. The speaker explained, in a brief but clear and interesting manner, the various steps followed in the production of lead in this district, beginning with prospecting for the mineral and following the movement of the rock in its course through the mill, whose product is the concentrate; then following the concentrate through the roasters and smelters, ending with the purified pigs of lead. A number of interesting views of mining properties and specimens of ore-bearing rock were shown. The speaker extended a very cordial invitation to all members to visit the mines of the Central Lead Company in order to better acquaint themselves with the nature of the very valuable and extensive lead deposits in this district.

Discussion was participated in by Mr. C. G. Reel and others.

The Chair announced as the subject of the paper for the next meeting, February 20, "A Historical Description of the Bridges over the Mississippi," illustrated by lantern slides, by Mr. F. B. Maltby.

It was decided that this meeting be an open one, and that members be requested to bring their friends, and make special effort to have a large attendance of ladies.

Adjourned to an adjoining room, where lunch was served.

W. G. Brenneke, *Secretary.*

521st Meeting, St. Louis, February 20, 1901.—Held at 1600 Lucas Place, 8.15 p.m.; President Spencer presiding.

Thirty-six members and eighteen visitors, including ladies, were present.

As the minutes of the 520th meeting had been printed on the announcement circular, and mailed to each member of the Club, it was moved and seconded that the reading of these minutes be dispensed with, and that they stand approved as printed.

The minutes of the 315th meeting of the Executive Committee were read.

The application for membership of Mr. Louis Bendit was read and referred to the Executive Committee.

President Spencer announced that as there had been no meeting of the Executive Committee this week, no action had been taken on the applications for membership of Messrs. W. H. Henby and T. M. Post, but their applications would be considered at the next meeting.

Mr. Flad, Chairman of the Committee on Lantern, reported that the committee had selected a new lantern on trial and that the lantern selected would be used in illustrating the paper of the evening. Its cost is between $17 and $18, and the cost of operating it is about 11 cents an hour. A new reading lamp was also provided.

The subject of the evening was a paper by Mr. F. B. Maltby, entitled "A Historical Description of the Bridges over the Mississippi River." Taking the bridges in the order of their occurrence, from the falls of Saint Anthony down the river, the speaker gave a description of each bridge, stating the authority for building, the general dimensions of all spans and approaches, the types of trusses, the classes of material in piers and superstructures and such other prominent points as were worthy of mention. The speaker made no attempt to go into engineering details, but confined his paper to a brief

statement of facts of general information. The paper was completely illustrated by lantern slides, views of nearly every bridge on the river being shown.

As there was no discussion after the completion of the paper, adjournment was made to the library rooms, where the Entertainment Committee had made special arrangements to serve a light lunch.

E. B. FAY, *Secretary pro tem.*

Boston Society of Civil Engineers.

JANUARY 23, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock P.M.; President Alexis H. French in the chair; one hundred and forty-two members and visitors present, including ladies.

On motion of Mr. Howland, the reading of the record of the last meeting was postponed until the next meeting.

On motion of Mr. F. O. Whitney, it was voted that the Chairman be requested to appoint a committee of three to report to the meeting the names of five members to serve as committee to nominate officers. The Chairman appointed Messrs. F. O. Whitney, H. D. Woods and C. T. Main as the committee. Later in the meeting this committee reported, as a Nominating Committee, Messrs. F. W. Hodgdon, Dwight Porter, Henry Manley, R. S. Hale and C. R. Cutter, and they were chosen by the Society as its committee to nominate officers for the ensuing year.

On motion of Mr. Sherman, the thanks of the Society were voted to the Derby Desk Company for courtesies shown the members on the occasion of the visit to its manufactory this afternoon.

On motion, Mr. Henry Manley was appointed a committee to make arrangements for the annual dinner, and it was voted to make the usual appropriation for the incidental expense of the same.

Mr. Manley called attention to the death of Queen Victoria, which occurred since our last meeting, and told of the very gracious manner in which she received the American engineers on the occasion of their visit to Windsor Castle last June. In concluding he offered the following resolution:

Resolved, That this meeting desires to give expression to its feelings of sorrow and its sense of loss in the recent death of Queen Victoria; that it desires to do honor to her memory, remembering that amidst the multitude of events of the first importance in the world's history which have transpired during her long reign, she has always been quick to acknowledge the services of modern engineering, and to honor its representatives.

The resolution was adopted by a unanimous vote.

The literary exercises consisted of an entirely informal, but very interesting and instructive, talk by Dr. Desmond FitzGerald, describing the palaces on the Grand Canal in Venice. The talk was very fully illustrated by lantern views.

Adjourned. S. E. TINKHAM, *Secretary.*

FEBRUARY 20, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 7.50 o'clock P.M.; Vice-President F. W. Hodgdon in the chair; seventy-six members and visitors present.

The records of the December and January meetings were read and approved.

Mr. Fred. Rufus Davis was elected a member of the Society.

On motion of Mr. Brooks, the thanks of the Society were voted to the United States Steel Company for courtesies extended this afternoon to the members of the Society who visited its works at West Everett.

Mr. Caleb Mills Saville read the paper of the evening, entitled, "Submerged Pipe Crossings on the Metropolitan Water Works." The paper was illustrated by numerous lantern views of the work. At the conclusion of the short discussion which followed the reading of the paper, Mr. Dexter Brackett had thrown on the screen a number of views of some of the recent work of the Metropolitan Water Board.

Adjourned. S. E. Tinkham, *Secretary.*

Engineers' Club of Cincinnati.

120th Regular Meeting, Cincinnati, Ohio, January 17, 1901.—Dinner was served at 6.30 p.m.

The regular meeting was called to order at 8 p.m.; with Vice-President Bogen in the chair.

There were twenty-one members present: Messrs. Bert. L. Baldwin, Ward Baldwin, Bogen, Carlisle, Carpenter, Coney, Elzner, Fritsch, Gordon, Gray, Hauck, Hobart, Innes, Kittredge, Nicholson, Osborn, Punshon, Read, Warrington, Rabbe and Wilson.

There was also present, by invitation, M. Philippe Bauna-Varilla, the French engineer, who was for several years connected with the construction of the Panama Canal, and who came to this city on invitation of the Commercial Club, before which organization he appeared last evening and spoke on the subject of the various proposed routes for an isthmian water connection between the Atlantic and Pacific Oceans.

The regular business was, on motion, waived, and the reading of the paper for the evening, by Mr. A. L. Hauck, on the subject "Economies and Economical Appliances Used in the Manufacture of Coal Gas," proceeded with, after which M. Bauna-Varilla favored the Club with a very interesting talk on the relative merits, advantages and feasibility of the Panama and Nicaragua routes for a ship canal, his comparison showing the former to be the better.

A vote of thanks was tendered him for his interesting and timely lecture, and also to Mr. Hauck for his paper.

On motion, the Club adjourned.

J. F. Wilson, *Secretary.*

Civil Engineers' Society of St. Paul.

Regular Monthly Meeting, February 4, 1901.—Deferred election of officers for ensuing year resulted in the election of:

President—A. O. Powell, Asst. Eng. U. S.

Vice-President—A. W. Munster, Bridge Eng. C. G. W. Ry.

Secretary—G. S. Edmondstone, City Bridge Engineer.

Treasurer—A. H. Hogeland, Res. Eng. G. N. Ry.

Librarian—C. A. Winslow, City Eng.'s office, St. Paul.

Representative on Board of Managers for Association of Engineering Societies—Geo. L. Wilson, Asst. City Eng., St. Paul.

Percy E. Barber and Otto Luserke were elected members. The Secretary's report was read and placed on file. The Treasurer's report showed the Society to be free from debt, and a comfortable figure upon the credit side of ledger.

Constitution and By-laws amended changing meeting night from first to second Monday in each and every month.

Mr. H. J. Gillie, Superintendent Edison Electric Light Company, described terminal station within the limits of the city of St. Paul of the electric current generated of power house at St. Croix River Power Company at dam upon Apple River. Afterward members personally inspected the terminal station. Adjourned.

G. S. Edmondstone, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, February 1, 1901.—Called to order at 8.30 p.m. by President Marx.

The reading of the minutes dispensed with by order of the Chair.

Mr. Charles Burckhalter addressed the Society on the subject of photographing the solar corona by the aid of a rotating comma-shaped disk attached to a slide, invented by the lecturer, by which certain unequal exposures are obtained to suit the degree of brightness of the field to be photographed. Mr. Burckhalter exhibited, by means of lantern slides, a number of beautiful results of his observations of the last solar eclipse at Siloam, Ga., in May, 1900, and explained at length the mechanism that had made it possible to achieve these remarkable results in astronomical photography.

A vote of thanks was passed for the author, expressing the appreciation of the Society. Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Society of Western New York.

Regular Meeting, February 5, 1901.—Meeting called to order at 8 p.m.; the President being in the chair. The following members present: Messrs. Haven, Diehl, Tutton, Knapp, Knighton, Speyer, Norton, C. M. Morse, Geo. F. Morse, Sikes, Weston, Ricker, Kielland, Buttolph and Babcock.

It was voted that the minutes of the last regular meeting be approved as printed.

The Executive Board reported that they had considered the matter of rent. At the meeting just after the annual meeting a Committee on Rooms was appointed to consider the matter of rooms, and they have reported that they think we had better stay where we are. Since then notice has been received that after the first of May the rent of the room in Ellicott Square will be increased 15 per cent. Mr. Norton, Vice-President, was appointed a committee of one to further consider the matter, in order to find out what we had better do after the first of next May.

The Executive Board also reported that the Society had received applications from the following gentlemen: Edward Dennison Hooker and Stanley W. Hayes as members, and Leslie J. Bennett and Warren Rodney as associates. The applications were taken up separately, and on motion it was voted that they be referred to letter ballot.

The Executive Board also reported that the Society had elected the following gentlemen: Horace Corey Booz and David Augustus Decrow as members, James Franklin and Mathew S. Gardiner as juniors and Albert W. Caines, Samuel J. Dark and William Franklin, Jr., as associates.

The President.—The Executive Board sent a marked copy of the printed minutes to the gentlemen who were appointed as committees to read papers before the Society, and to several other gentlemen, and have receive replies as follows:

From Mr. S. W. Hayes, who was requested to read a paper on "The Proper Construction of Docks," asking to be relieved until after the coming summer.

From Mr. C. D. Watson, who said, on account of assignment to work in the South, he would be unable to read a paper at present.

From Mr. David Cuthbertson, who stated that he would be pleased to read a paper on "The Workings of the Weather Bureau" at the meeting of the Society in March.

From Mr. C. R. Neher, who said he would read a paper on "Concrete Construction" at the March meeting.

The Librarian made a brief report.

Mr. Ricker, who had been appointed by the President as a committee of one on Docks, addressed the Society as follows:

Mr. President and Gentlemen.—All of you will perhaps remember the collapse of the two ore docks in Buffalo,—one at the Union Furnaces, the other belonging to the West Shore Railroad Company. I am now rebuilding the Furnace Company's dock, and will tell you what I am doing, but before outlining the plan, for the information of those who are not familiar with the conditions, will explain the failure as far as I can. At the foot of Hamburg street, on the east bank of the river, are located the furnaces of the Union Furnace Company, a combination of the three old companies. Here was built a pile and timber dock of the ordinary type of construction, and back of this dock was stored a great many tons of ore. A Brown hoist was erected on the dock, and the ore carried back on a traveler and dropped, but no part resting on the timber structure itself. Immediately back of the dock was a car track. The piles for a distance of 50 feet back were pretty staunchly anchored with 2-inch tie rods, the rods being looped over a rail, which was coupled up with fish plates in front of the inner row of piles, so that the dock was pretty well tied in. The penetration of the piles was from 4 to 5 feet only, and this fact, in addition to the nature of the soil itself, was the cause of the dock failing. Of course, in a pile and timber dock there is little resisting power to lateral outthrust, and an overload of ore simply pushed the whole dock out. After its failure there was but little left of the dock, as the whole structure moved out into the river from 20 to 35 feet. The tie rods being fastened in near the top the footing gave way before the rods broke. Some rods snapped off, in other cases pulled through the anchor bolts, and many piles were broken off. The rock underlying is practically level, there being a slight dip to the east, so that what in-

clination there was was against the thrust of the ore. The rock is perfectly smooth and there was nothing to hold the feet of the piles, which slipped along as naturally as could be, and the ore, of course, went to the bottom. It was afterward dredged out with a clam shell dredge and taken back and stored in the yard.

With a dredge the old piles were drawn out and the earth dredged back 30 feet wide down to the rock. We are putting in cribs of 12 x 12 hemlock that are 26 feet wide with two bays of 13 feet each, and are loaded with stone. The cribs reach to a height of about 22 feet. On the top and front of these cribs it is proposed to form a concrete facing of truncated triangular form, 8 feet on the bottom and about 4 feet on top, with the slope on the inner side. The rock filling will be brought up over the entire width of the crib to the top of the concrete. The space made by dredging the earth at the natural slope back of the cribs will be packed full of slag, so that a large part of the treacherous earth back of the dock will be replaced by this slag filling, and so much of the thrust as was due to the earth will be taken away by using this more substantial material for back filling. The new dock will be 550 feet long. That portion of the unharmed pile dock immediately south of the cribs will be allowed to remain, but will not be used for the storage of ore.

The President.—Is this the first dock or wharf that has been built in Buffalo with a concrete face?

Mr. Ricker.—So far as I know, it is. In regard to facing the concrete, we will protect this from bruising by oak timber waling strips and a heavy cap of same material.

Mr. Diehl.—The underlying rock is level?

Mr. Ricker.—Almost level. At the south end of the dock the water is 24 feet deep, at the north end it is probably not over 18 feet,—possibly 19 feet.

Mr. Diehl.—How was the width of the crib determined—what formula did you use?

Mr. Ricker.—The usual formulas for retaining walls. My sole object was, of course, to get enough stone in the cribs to resist the thrust of the ore piles that would be imposed on the earth immediately back of the dock. And as a further precaution against possible movement of the cribs we shall bore into the rock and drop car axles into these holes vertically, each hole being 3 feet deep, the axles 6 feet long.

Mr. Kielland.—How deep is the water in front of the cribs?

Mr. Ricker.—Eighteen feet.

Mr. Sikes.—Was there any floor under the ore piles?

Mr. Ricker.—Yes. Plank laid on sleepers on the ground. When we considered the cost of a pile and timber dock, we found that the piles must be 5 feet centers, and the caps would have to be 30 inches deep, and a corresponding floor system.

Mr. Norton.—I am somewhat acquainted with the geology of that section, having taken soundings for the rock dredging which the city has done from Ohio to Hamburg streets recently. The rock is worn smooth by glacial action, showing scratches, being mainly very smooth. Immediately above this is a layer of hard pan, containing much of the bed rock in various sized fragments. I believe it to consist largely of the broken and pulverized underlying rock. It was found difficult to drive steel rods through a few feet of this to determine the depth of the rock.

I should like to ask Mr. Ricker if he removes this hard pan with a dredge so as to place the cribs on the rock? And, also, if he thinks that the piles of the dock which failed were driven into this hard pan or through it? I hardly think it possible to drive an unshod pile through it.

Mr. Ricker.—I think it extremely doubtful if the original piles penetrated this hard pan, as some were found broken at the point. We were able to remove the hard pan with dredges.

Mr. Norton.—I believe this formation underlies most of the Buffalo River Valley. It is found near its mouth, and also in Cheektowaga. In 1890 I sounded the rock in the river at the Watson elevator. Vessels grounded on what appeared to be rock bottom. A few drivings showed rock to be from 1 to 3 feet below bottom. Borings showed this layer of hard pan which the smaller dredges then in use were unable to strip off. Mr. Stewart, who is building the sub-structure for the D. L. and W. R. R. swing bridge on Water street over the Evans Slip, told me he expected to found the concrete abutments on rock. I told him it was doubtful if the dredge he had would remove the hard pan. He has since told me that it was not removed, but the concrete laid on top of the two feet of hard pan overlying the rock. I do not know whether they found it impossible to do so, or considered it as good as the concrete with which it would be replaced. At the high points of the bed rock the hard pan is often missing. In making some sketch plans for excursion docks, when the matter was recently under discussion, I provided for a construction quite similar to that used by Mr. Ricker at the furnace dock.

The President.—Mr. Speyer, you found the same formation at Clinton street, did you not?

Mr. Speyer.—Yes, sir. Also at Smith-Seneca streets. There was about 3 feet of this hard pan on top of the rock.

The President.—On which the retaining walls now rest?

Mr. Speyer.—Yes, sir.

Mr. Sikes.—The same formation was found under the U. S. Breakwater.

Mr. Kielland.—When we built the coal trestle at Cheektowaga for the Lehigh Valley Railroad we stripped about an acre of the rock, which showed the same glacial markings, and the boulders which must have made the markings on the rock. The rock was polished in many places, and can be seen there to-day. We found the same formation that you find everywhere else. In some places we found the hard pan overlying the rock, in other places the rock was clean. The hard pan was from 3 to 4 feet thick, and filled with these boulders.

Mr. Tutton.—I would like to extend the remarks, which may be of interest to some of the members. I built a dock south of the Union Iron Works. We drove test piles from 80 to 90 feet before we brought up on the rock. That is, we *think* we brought up on the rock, we are not positive. There seemed to be an estuary running through South Buffalo, crossing the city line about where the Abbott road crosses. There seemed to be gravel at about 25 to 30 feet. This we passed through and drove our piles 20 or 30 feet farther; when we passed through this our piles dropped through. This dock was designed to carry from 200 to 400 pounds per square foot, of ordinary construction. As near as I can remember the dock was 40 feet wide on top. The piles, I think, were 7½ feet centers. The dock gave way in a different manner than the one

being replaced by Mr. Ricker. The ore sank down in the earth and the dock was lifted in the air 10 or 12 feet. This dock was replaced by Mr. Kielland, I having left the road in the meanwhile.

At the time the canals were cut across the Tifft farm the foremen of the dredges ran a race to see which could take out the most material, and I think they cut through this layer of hard pan, and this probably accounts for the failure of this dock.

Mr. Kielland.—I was Division Engineer of the Lehigh when this dock failed. A Brown hoist was constructed on the dock, resting on a pile foundation. The ore was piled from 25 to 30 feet high, the toe of the pile being from 50 to 60 feet from the front of the dock. Very suddenly the pile of ore sank and the dock rose in the air. I came out shortly after the accident. We took soundings in front of the dock and commenced immediately to reconstruct it. We cut off the piles. The Brown hoist was in good shape, only the joints were sprung. We cut off the piles which had been driven out of shape and drove other ones. We got the ore out and placed it farther back. It cost but little to repair the dock, and it is in use to-day.

Mr. Geo. F. Morse, Asst. Engineer L. V. R. R., said that the company had instructed him to make an investigation as to the proper load, etc. He had investigated the matter and had recommended to keep the toe of ore piles 70 (seventy) feet away from front of dock, to dump the ore in conical piles and not in ridges or to limit the load not to exceed more than 1500 to 2000 pounds per square foot of surface.

Mr. Ricker.—Do you suppose the ore sank down to this layer of hard pan and rested on it?

Mr. Kielland.—I think it did. It rested in a pocket. The Lehigh has the biggest dock in Buffalo, and they have not done anything especial to construct a dock to care for this ore. The only precaution is to keep ore piles far enough back from front of dock.

Mr. Ricker.—All these failures seem to indicate that pile docks in this soil will fail with a load of about 1½ tons to the foot, about the load which has produced the failure in every case.

Mr. Sikes.—This hard pan shows at the Ridge road. There the rock is only about 25 feet below the surface, at Tifft street 70 to 80 feet. This hard pan is about 18 feet from the surface at the city line and 31 feet at Tifft street.

Mr. Tutton.—They find the same thing at the steel plant, and at Smokes Creek.

Mr. Kielland.—I want to tell another thing in regard to docks on the Tifft farm. The Lackawanna when they built their dock only drove their piles to this sand or hard pan. Just south of the Buffalo Creek bridge the hard pan is about 30 to 35 below water. This dock has been loaded very heavily as a rail and iron dock. It has kept its general elevation well.

The President thanked Mr. Ricker in behalf of the Society for his very interesting talk by means of which the Society has had a most instructive session.

The matter of sending out invitations to the different Societies in North and South America was taken up, and on motion of Mr. Ricker, seconded by Mr. Knapp, it was unanimously voted that the subject matter be referred to the Executive Board with power.

Meeting adjourned at 11 p.m. G. C. Diehl, *Secretary.*

MEMBERS ARE ADVISED . .
THAT THEY CAN OBTAIN

Reprints or Extra Copies of their Papers

AT THE FOLLOWING RATES:

	4 pages or less	5 to 8 pages	9 to 16 pages	17 to 24 pages	Covers extra.
100 Copies . .	$2.25	$4.00	$5.50	$9.25	$2.25
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1000 " . .	4.50	8.75	12.50	21.00	4.50

An extra charge will be made for printing and inserting such illustrations as are not printed on the same pages as the text, and for enameled paper, when this is used, but it is of course impossible to name rates for this in advance.

When reprints are wanted, notice of the fact, stating how many are desired and whether they are to be furnished with covers, should accompany the paper when it is sent to the Secretary of the Association.

If the paper has been discussed, please state whether it is desired that the reprint shall contain the discussion.

JOHN C. TRAUTWINE, Jr., Secretary,
257 SOUTH FOURTH STREET,
PHILADELPHIA.

Association of Engineering Societies.

Vol. XXVI. | MARCH, 1901. | No. 3.

PROCEEDINGS.

Proceedings of the Fourteenth Annual Meeting Held in Butte, Montana, January 10 to 12, 1901.

The fourteenth annual meeting of the Montana Society of Engineers was held in Butte, Mont., from January 10 to 12, 1901. On the evening of the 10th the Society held a "smoker" in their headquarters, Rooms 16 and 17, Tuttle Building. Light refreshments were served and the evening was spent in a very enjoyable social gathering.

January 11 was devoted to visiting points of engineering interest in and about Butte. In the morning the party met at the Society headquarters, and made a trip over the Butte Street Railway to Walkerville; arriving at the new reservoir of the Butte City Water Company, they were escorted by the chief engineer, Mr. Eugene Carroll. They then paid a visit to the Montana State School of Mines, where they were welcomed by Prof. N. R. Leonard, and shown the many points of interest in the new institution. In the afternoon the members separated into smaller parties and visited the various mines and smelters, some going underground to view the riches of mother earth, some to the smelters to study the various methods of treating ore, and others to inspect the splendid machinery of the various hoisting plants used at the different mines, points of interest in which Butte can equal if not excel any city in the world.

At 8.30 P.M. Mr. H. V. Winchell, chief geologist for the Anaconda Copper Mining Company, delivered a very interesting lecture, illustrated with stereopticon views, on "The Iron Mines of Minnesota," in the Council Chamber of the City Hall.

The annual business meeting was held at the Council Chamber, City Hall, Butte, Mont., January 12, 1901.

The meeting was called to order at 10 o'clock A.M. by the President, Mr. Blackford, in the chair.

The Secretary called the roll of members present, as follows:

Geo. T. Wickes, F. L. Sizer, R. R. Vail, Albert Koberle, W. J. Flood, Eugene Carroll, B. D. Whitten, S. H. Crookes, W. H. Williams, J. H.

Harper, R. A. McArthur, Carlisle Mason, C. W. Goodale, G. W. Tower, Jr., C. D. Vail, E. C. Kinney, Wm. Zaschke, A. W. Catlin, C. H. Bowman, C. H. Moore, C. W. Paine, N. R. Leonard, Eugene Sickles, August Christian and C. V. Page.

The Secretary read the minutes of the meeting held December 8, 1900.

The minutes were approved as read.

The Secretary presented applications for membership as follows:

Nathan R. Leonard, President of the Montana State School of Mines.

Reno H. Sales, assistant engineer for the Boston and Montana Company, at Butte.

Charles Warner Paine, engineer in charge of the new works for Butte City Water Company.

Sam. Edward Davis, head surveyor for the Boston and Montana Company, Butte.

Rudolph Joseph Decker, mechanical engineer of the Montana Ore Purchasing Company, Butte.

William White, architect, Butte.

Edgar James Strasburger, civil engineer, Butte.

Frederick John Rowlands, salesman of mining machinery, Butte.

Stephen Pearl Wright, proprietor of the Western Mining Supply Company, Butte.

Charles John Adami, mining engineer for the Butte and Boston Mining Consolidated Company.

On motion of Mr. Sizer the applications were referred to the Trustees.

The Secretary presented further applications as follows, which were similarly referred:

Burt Adams Tower, mining engineer with the Montana Ore Purchasing Company, Butte.

Alfred Frank, mining engineer with the Montana Ore Purchasing Company, Butte.

Richard Austin Lacey, engineer with the Montana Ore Purchasing Company, Butte.

Messrs. Whitten and Koberle and Professor Williams were appointed tellers to canvass ballots for officers.

The Secretary read his report, as follows, which, upon motion, was ordered filed:

REPORT OF SECRETARY AND LIBRARIAN FOR THE YEAR ENDING JANUARY 12, 1901.

BUTTE, MONT., January 12, 1901.

To the President and Members Montana Society of Engineers.

GENTLEMEN:—I beg leave to submit the following as my report for the year ending January 12, 1901:

FINANCIAL STATEMENT.

RECEIPTS.

Cash in Treasury, January 13, 1900	$355.11
Dues collected	821.50
From sale of old furniture	30.00
Total	$1,206.61

DISBURSEMENTS.

To expense 13th annual meeting	$97.05
To Association of Engineering Societies	222.95
To rent of headquarters and janitor's services	261.00
To furnishing of headquarters	256.88
To printing and stationery, including 250 copies Constitution, By-Laws, etc.	148.75
To Secretary's salary	100.00
To stamps, envelopes, express charges, telegraphing, hauling, P. O. box and sundries, as shown in vouchers attached to Secretary's bills	46.59
Total	$1,133.22
Leaving a balance on hand January 12, 1901	73.39
	$1,206.61

All the bills against the Society have been paid up to date excepting the bill for printing the proceedings of the thirteenth annual meeting, which has been held pending correction.

MEMBERSHIP.

The following table shows the membership of the Society of all grades at the beginning and end of fiscal year:

	Jan. 13, 1900.	Jan. 12, 1901.
Honorary members	4	4
Active members	117	110
Associate members	21	28

During the year one member resigned, fourteen members were dropped for non-payment of dues and not conforming to requirements of membership, and seven members, through removal from the State, were removed from active to associate list. Sixteen new members were elected during the year.

The Society lost one member by death during the year, the same being Mr. J. S. B. Hollinshead, of Butte, whose sudden death took place at his home on July 19, 1900.

Four papers were read and two discussions were had at the various meetings during the year. Two hundred and fifty copies of the Constitution and By-Laws, containing in addition the list of officers and members, were published, and distributed to the members of the Society. Two hundred and fifty copies of the proceedings of the thirteenth annual meeting were published. The same included also a synopsis of the meetings of the year 1899, and all the papers read before the Society during that year, and the list of officers and members.

Library. The books of the Society have been shelved in new Werneke bookcases, but no provision has yet been made for properly taking care of the various smaller pamphlets and transactions of various Engineering Societies.

The following magazines are regularly received: *Engineering and Mining Journal, Engineering Record, Construction News, Railway Age, Indian Engineering, Railway and Engineering Review, Irrigation Age, Modern Machinery, Railway Master Mechanic, Journal of the Western Society of Engineers* and the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Many smaller books, pamphlets and transactions of various Societies have been received and proper acknowledgment made.

Respectfully submitted,

R. A. McArthur, *Secretary.*

A regular meeting of the Montana Society of Engineers was held March 9 in their headquarters, Rooms 16 and 17, Tuttle Building, Butte, Mont., with nineteen members and two visitors present; Vice-President August Christian in the chair.

Applications of Ai Arthur Abbott and Albert James Flood were read and accepted for balloting. Messrs. Adami and Tower were appointed tellers to canvass ballots for membership, and reported Messrs. Richard Austin Lacy, Steven P. Wright and Fred. T. Greene elected as members.

Report of Annual Meeting Committee was read and accepted and committee discharged.

The committee appointed to revise the Constitution to create a junior membership submitted the following report:

PROPOSED AMENDMENT TO THE CONSTITUTION.

ARTICLE II.

MEMBERS.

Section 1. The membership of this Society shall be designated as Active Members, Associate Members, Corresponding Members, Junior Members and Honorary Members.

Sec. 2. An active member shall be a civil, mechanical, mining, electrical or other professional engineer; an architect, geologist, metallurgist or analytical chemist. He shall have been in active practice of his professional work for at least four years, or in responsible charge of professional work for at least two years, and shall be qualified to design and direct engineering work, or capable of carrying on the work of his profession. Credits from a school of recognized reputation in the above profession shall be considered as equivalent to one-half the time they represent as active practice. The performance of the duties of a teacher in schools of high grade in the above professions shall be accepted as equivalent to an equal number of years of responsible charge of professional work.

Sec. 3. An associate member shall be a person who by scientific acquirements or practical experience has attained a position in his special pursuit qualifying him to co-operate with engineers in the advance of engineering knowledge or practice.

Sec. 4. A corresponding member must have his residence outside of the State of Montana, and must be competent to contribute valuable information on engineering questions. This grade will also include members of the Society who have removed from the State and wish to temporarily withdraw from active participation in the affairs of the Society.

Sec. 5. A junior member shall have had active practice in his branch of engineering for at least two years, or the equivalent of the same as stated in Section 2 of this Article. A junior member shall be transferred to active membership as soon as he becomes eligible therefor.

Sec. 6. An honorary member shall be a person of acknowledeged eminence in one of the professions enumerated in Section 2 of this Article.

Sec. 7. Active members, associate members and junior members shall be designated at resident and non-resident members. Those living within thirty miles of the court house in Butte shall be classed as resident members.

Sec. 8. Any member of the Society who removes from the State and wishes to temporarily withdraw from active participation in the affairs of the Society may do so on filing with the Secretary a written declaration of his intentions and paying to the Secretary all accumulated fees or other indebted-

ness due the Society. He will then be classed as a corresponding member, and will be subject to no dues or assessments. He may return to membership by giving written notice to the Secretary and paying to him all assessments and dues for the current year.

SEC. 9. Any member of any other Society in the Association of Engineering Societies, in good standing, may become a member of this Society, when duly elected as described in Article IV of the By-Laws, without paying the initiation fee, and with a release from the annual dues for such period, not over one year, as he may show by certificate he has paid in advance in the Society from which he comes.

ARTICLE IV.

SECTION 1. Active members alone shall have the privilege of voting and holding office. Associate members are entitled to vote, but are not eligible to hold office.

Substitute in Articles III, IV and V of the Constitution the words "Active and Associate Member" in place of "Member" where it refers to voting and "Active Member" where it refers to holding office.

PROPOSED AMENDMENT TO THE BY-LAWS.

ARTICLE IV.

ADMISSION TO THE SOCIETY.

SECTION 1. All candidates for admission to the Society shall make application in writing, etc.

SEC. 6. The annual dues of all resident active members and associate members shall be $8; resident junior members and non-resident active members and associate members $6; non-resident junior members $4. Honorary and corresponding members shall be subject to no dues or assessments. All dues shall be paid to the Secretary on or before the first regular meeting in February of each year.

Substitute in the By-Laws the words "Active and Associate Member" in place of "Member" where it refers to voting and "Active Member" where it refers to holding office.

A motion was passed requesting the report of the committee be printed and sent to the members of the Society inviting a written discussion to be presented at the next regular meeting.

Mr. McArthur presented the following resolutions, which were unanimously adopted:

WHEREAS, A Divine Providence has seen fit to remove from our earthly associations another member of this Society; be it

Resolved, That in the death of David Walker Hardenbrook we recognize the loss of a member whose kindly disposition and gentle manner have won the esteem of his entire acquaintance, and whose quiet and faithful performance of his engineering duties has commanded the respect and confidence of all his professional associates.

Resolved, That this sentiment be spread upon the minutes of this meeting, our sympathy be extended to his friends and relatives and a copy of this action be forwarded to his bereaved family.

A motion was passed requesting Mr McArthur to prepare a biography of the deceased to be presented at the next regular meeting. Messrs. Moore, Harper and Weed were appointed on a committee to select a design for a badge of the Society.

Mr. Walter H. Weed, United States Geographical Survey, entertained the Society with an interesting talk of the mines recently visited by him in Mexico. The geological conditions around Chihuahua and Parral, together

with many interesting features of the country, were described in a very entertaining manner.

NOTICE.—The attention of the members is especially called to the report of the Committee on Revision of the Constitution presented above, and any desirable changes or suggestions should be sent in at once to the Secretary.

This will be presented at the next regular meeting, at which time the matter will be further considered.

RICHARD R. VAIL, *Secretary.*

THE PRESIDENT.—Gentlemen, you have heard the report of the Secretary. What is your pleasure?

It was moved and seconded that the report be placed on file, and upon being put to vote was duly carried.

THE PRESIDENT.—The next order of business is the report of the Treasurer.

MR. HARPER.—I would say that my report is hardly complete. I am expecting two or three further items that I intended to embrace in the report. Mr. McArthur and myself, however, have checked this morning, and have reached a practical agreement. There is at the present time $73.39 in the Treasury, as he states in his report.

THE PRESIDENT.—When will you promise us your formal written report, Mr. Treasurer?

MR. HARPER.—It will be filed some time during the afternoon, probably by two o'clock.

THE SECRETARY.—If permitted, I will say in that connection, that the items to which Mr. Harper refers are three orders, which were issued January 8, and they are now in the hands of Mr. Moulthrop, who is one of the trustees, and I telephoned him this morning to see if I could get them, and I have been expecting them here. That is the reason that we could not incorporate them in that report.

THE PRESIDENT.—Gentlemen, you have heard the report of the Treasurer. What is your pleasure?

MR. GOODALE.—I move that the Treasurer be given further time to make his report.

The motion was seconded, and upon being put to vote was declared carried.

THE PRESIDENT.—The Secretary will please read the report of the committee that canvassed the ballots for the election of officers.

THE SECRETARY.—The report reads as follows:

"MR. PRESIDENT:—Your committee, appointed to canvass the ballot for officers for the year 1901, desire to report as follows: There have been forty-six ballots cast, of which Frank L. Sizer received forty-six for President; August Christian forty-six for First Vice-President; George T. Wickes forty-six for Second Vice-President; Richard R. Vail forty-six for Secretary and Librarian; Joseph H. Harper forty-six for Treasurer and member of the Board of Managers of the Association of Engineering Societies, and Bertram H. Dunshee forty-six for Trustee for three years.

"Respectfully submitted,

"ALBERT KOBERLE,
"W. H. WILLIAMS,
"B. D. WHITTEN,
"Committee."

The President.—Gentlemen, you have heard the report of the committee who have canvassed the ballots. The report shows that the candidates for officers were all elected unanimously.

You have elected for President of the Society for the ensuing year one of the charter members of the Society, an engineer very widely and favorably known throughout the State and elsewhere, and one who will conduct the affairs of the Society with dignity and ability.

I will appoint Mr. Kinney and Mr. Tower to escort the newly-elected President to the chair.

(The committee performed its office.)

I take pleasure in introducing Mr. Frank L. Sizer as President of the Society. (Applause.)

The newly-elected President took his seat in the President's chair, and addressed the Society as follows:

The President.—Gentlemen of the Society, it is with mingled feelings of pain and pleasure that I stand before you to-day,—pleasure because I regard it an honor to be selected as your President, and pain because I have always looked upon this office as one belonging to the older men of the Society, and I realize now, when this honor is thrust upon me, that I can no longer count myself one of the young men. I admit being a charter member of the Society, and in that sense an old man, but it seems only a few short years ago that I labored under the disadvantage of being thought too young to take charge of any important engineering work. But that is a disability we can all outgrow, and I feel that the only thing of moment is to know whether a man can do his work thoroughly well.

I am growing to take more and more pride in the accomplishment of one piece of work in our beloved profession, and I feel that I shall be thoroughly satisfied with my life if I can succeed in rearing one monument that will be lasting. In this respect I feel that the civil engineer and the architect have the advantage, for it has truly been said of the mining engineer that his province is to tear down rather than to build up,—in other words, "to tear the insides out of the earth" seems to be a particular delight of that branch of the profession to which I have the honor of belonging.

I have always taken great pride in this Society. While I have done much less than many others to build it up and strenghten it, I have yet tried to do my part in those years in the past, when, with our good President Haven,—the only one who ever had the audacity to demand a "third term,"—I assisted in putting hats on chairs to represent a quorum at some of our monthly meetings. But the Society has outgrown the age of tottling, and I feel it is thoroughly able to stand alone.

I am very much gratified with the growth of the Society. In four years we have just doubled our membership, and it seems to me that although our grand young treasure State has developed wonderfully in this same period, our Society can say truly that it has more than justified the fondest hopes of its most sanguine members. It is certainly a gratification to know that in our membership is now contained nearly all of the most prominent members of the professions which are eligible to election in the Society throughout the State, and I feel that there is great need of still further push for the increase of our membership, and gathering in the younger men in the profession. The province of this Society is broad, the scope of it is large, and yet the work to be done is still larger; the opportunities for advancement of

the members of this Society in every direction are very much greater than most of us realize. When I look over the list of members I can hardly justify the choice of your Nominating Committee as regards myself, but with the assistance of the worthy Vice-Presidents and each and every member of the Society, I shall endeavor to merit your approbation in the years to come. (Applause.)

Mr. Wickes, second Vice-President, addressed the Society as follows:

Gentlemen:—I was not aware that the Vice-President was to be called upon to take a prominent position in the chair beside the President. I am very much obliged to you for the honor you have conferred upon me, which was entirely unexpected. Although I am one of the charter members. I have not taken very active part, in fact no part at all, in the meetings, but that has been largely due to the fact that my work has been so out of the way, even when the Society held its meetings in Helena, and while my family was there I was away most of the time, and at the times of the meetings it has not been possible for me to go to them. I have, however, always taken a great interest in the doings of the Society, and have always been glad to know that the engineers were combining and would work together. I think that is a feature, generally, that the engineers have not heretofore pulled together as much as they should, as much as many other organizations in the professions do pull together and support each other; but there is no way in which they will pull together or bring about that result better than to be in an organization of this character, and I hope that it will continue to grow and become stronger; and as our President has said that an effort will be made to make the Society a larger and a stronger organization. I thank you for the honor conferred.

Mr. Vail, the newly-elected Secretary, thanked the Society for the honor conferred upon him by his election, and expressed the hope that he might be enabled to perform his duties creditably.

Mr. Tower, Chairman of Committee of Arrangements for Annual Meeting, requested that the members of this Society contribute to the treasury of the committee $3.50 each for the purpose of defraying expenses.

On behalf of Mr. H. W. Turner, Chairman of Committee on Transportation, Mr. McArthur reported that Mr. Turner had fulfilled the duties imposed upon him and had secured rates from all the railway companies concerned.

The meeting then adjourned until 2 P.M.

AFTERNOON SESSION.

The Society was called to order at 2 o'clock P.M. by the President F. L. Sizer in the chair.

The President.—We finished Order of Business No. 6, with the exception of some letters which were received by the Society, and I will ask Mr. McArthur to read those letters.

The Secretary read letters of regret from William Appleton Haven and E. H. Beckler, Honorary Members of the Society, upon their inability to be present.

The Secretary was directed by the President to respond to the letters.

The President.—It will be proper at this time to hear the report of the Treasurer.

The Treasurer, Mr. Harper, submitted his report to the Society.

MONTANA SOCIETY OF ENGINEERS IN ACCOUNT WITH JOSEPH H. HARPER, TREASURER.

By amount received from Forrest J. Smith, ex-Treasurer		$227.11
" " " " R. A. McArthur, Secretary		851.50
" " " " A. S. Hovey		128.00
		$1,206.61
To expenditures (orders Nos. 1 to 35) as per vouchers	$1,133.22	
Balance in treasury	73.39	
	$1,206.61	

The Treasurer.—The vouchers referred to are herewith tendered. They are complete with one exception. The last order, or the last draft that I sent to Mr. Trautwine, Secretary of the Association, has not yet been returned. I will make it a personal matter and see that that is properly attached when it does arrive.

The Treasurer's report was ordered referred to the Trustees. On motion of Mr. Carroll, the Secretary was directed to write letters of thanks to railroad companies and others for courtesies extended to the Society.

On motion of Mr. Wickes, the visiting members expressed their thanks for the hospitality extended to them by the resident members.

On request of the President, the Secretary read Section 3 of Article II as follows: "Candidates for admission to the Society, as members, must have been engaged for at least five years in some branch of engineering or architecture, or have been graduated as engineer or a manager of a railroad, canal or other public work; a geologist, chemist or mathematician; a manager of a mine or metallurgical works; or one who from his scientific acquirements or practical experience has obtained eminence in his special pursuit, qualifying him to co-operate with engineers in the advancement of professional knowledge, but may not himself be practicing as an engineer."

Mr. Goodale urged the advisability of establishing a class of associate members, and asked for discussion of the subject.

Mr. Blackford called attention to provisions of Section 5, Article II, as follows:

"Any member of the Society who removes from the State and wishes to temporarily withdraw from active participation in the affairs of the Society may do so on filing with the Secretary a written declaration of his intentions and paying to the Secretary all accumulated fees or other indebtedness due the Society. He will then be classed as an Associate, and will be subject to no dues or assessments. He may return to membership by giving written notice to the Secretary and paying to him all assessments and dues for the current year."

Then Mr. Harper suggested the title "Junior Members," and on motion of Mr. C. D. Vail, a committee of three was appointed to propose an amendment to the Constitution regarding the matter of membership, and to provide for Associate and Junior Memberships.

The Chair appointed Messrs. Goodale, Charles D. Vail and Blackford as members of the Committee on Revision of the Constitution. On request of Mr. Blackford, he was excused from service on the committee, and Mr. McArthur appointed to fill the vacancy.

Mr. Christian, First Vice-President, expressed his thanks for the honor conferred in his election.

The Secretary read a letter from Mr. Charles H. Repath, giving an account of the death of Mr. Hollinshead and a short sketch of his life's history.

Mr. Carroll voiced the regret of the Society respecting the death of Mr. Hollinshead, and dwelt upon the enthusiasm with which he took part in every movement for the benefit of the Society.

On motion of Mr. Carroll, seconded by Mr. Blackford, the Secretary was instructed to prepare a memorial of Mr. Hollinshead for publication in the Journal of the Association of Engineering Societies. The President appointed Messrs. Moore, Goodale and Repath members of the committee to prepare this memorial.

On motion of Mr. McArthur, the Secretary was instructed to have 250 copies of the proceedings of this meeting published and distributed to the members of the Society.

Mr. Carroll urged that the publication of these proceedings be expedited.

Mr. Harper mentioned the annoyance caused by the omission on the part of the printers to supply the illustrations accompanying his paper on the Big Hole Dam, in the reprints furnished the Society.

On motion of Mr. Carroll, the motion was amended so as to instruct the Society to procure from the Secretary of the Association of Engineering Societies a reprint of the proceedings of the annual meeting, including the papers presented, and the motion as amended was carried.

Mr. F. W. Blackford, retiring President, presented his annual address and expressed his thanks to the members for the courtesy extended to him during his term of office.

The President complimented Mr. Blackford upon his instructive and entertaining address.

The Society then adjourned.

The banquet held at the McDermott Hotel commenced at 9 o'clock. The following members were present: F. W. Blackford, Eugene Carroll, A. W. Catlin, August Christian, S. H. Crookes, B. H. Dunshee, W. J. Flood, C. W. Goodale, F. P. Gutelius, J. H. Harper, A. E. Hobart, E. C. Kenney, Albert Koberle, M. L. Macdonald, Carlisle Mason, R. A. McArthur, E. R. McNeill, C. V. Page, B. R. Putnam, Eugene Sickles, F. L. Sizer, G. W. Tower, Jr., H. W. Turner, C. D. Vail, R. R. Vail, B. D. Whitten, F. W. C. Whyte, G. T. Wickes, W. H. Williams, E. H. Wilson, H. V. Winchell, C. H. Bowman and Wm. Zaschke. Also the following guests: B. A. Tower, Alfred Frank, R. H. Sales, C. J. Adami, S. P. Wright, E. J. Strasburger, R. J. Decker, C. W. Paine, Harry Gallwey, J. E. Dawson, C. C. Rueger.

Mr. Eugene Carroll acted as toastmaster, and following toasts were replied to:

"The President of the United States," by C. H. Moore.

"The Montana Society of Engineers," by F. L. Sizer.

"The Educational Institutions of Montana," by W. H. Williams.

"The Geologist," by H. V. Winchell.

"The Mining Engineer," by Geo. T. Wickes.

"Our former President, W. A. Haven," by C. W. Goodale.

"The Irrigation Engineer," by E. C. Kenney.

"The Ladies," by Geo. W. Tower, Jr.

"The Civil Engineer in British Columbia," by Fred. Gutelius.

Besides various stories and short talks by Messrs. Koberle, Wright, Dawson, Christian, Wilson and others.

Boston Society of Civil Engineers.

Boston, March 20, 1901.—The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.35 o'clock p.m.; President Alexis H. French in the chair. Ninety-two members and visitors present.

The record of the last meeting was read and approved.

Messrs. William C. Ogden, John K. Perkins, Lewis D. Thorpe and Andrew W. Woodman were elected members of the Society.

The Secretary read his annual report, which was accepted.

The Treasurer read his annual report, which was accepted and ordered to be placed on file.

Mr. Corthell presented and read the annual report of the Committee on Excursions, which was accepted.

The Librarian presented and read the annual report of the Committee on the Library, which was accepted.

Professor Allen presented and read the annual report of the Committee on Quarters, which was accepted.

The Secretary read the annual report of the Board of Government, which was also accepted.

On motion of Professor Swain, it was voted to adopt the recommendation of the Board of Government, that the incoming board be directed to petition the General Court at its next session for authority to enable the Society to hold a larger amount of personal and real estate.

The recommendation that the sum of $75 be appropriated for the purchase of standard engineering books, was also adopted.

On motion of Mr. Stearns, it was voted to refer to the Board of Government, with full powers, the question of continuing the several special committees of the Society, and the selection of the members thereof.

Messrs. Henry D. Woods and Henry A. Varney, the tellers of the election, submitted the result of the letter ballot for officers.

In accordance with their report the President announced the election of the following officers:

President—Lawson B. Bidwell.

Vice-President (for 2 years)—X. Henry Goodnough.

Secretary—S. Everett Tinkham.

Treasurer—Edward W. Howe.

Librarian—Louis F. Cutter.

Director (for two years)—William M. Brown, Jr.

The President then introduced Mr. J. A. Ockerson, of St. Louis, a member of the Mississippi River Commission, who read the paper of the evening, entitled, "The Mississippi River; Some of Its Physical Characteristics, and Measures Employed for the Regulation and Control of the Stream." The paper was fully illustrated by stereopticon views.

On motion of Professor Swain, the thanks of the Society were voted to Mr. Ockerson for his kindness in reading his valuable paper before the Society.

Before declaring the meeting adjourned the President introduced the President-elect, Mr. Bidwell, who thanked the members for the honor which they had conferred upon him.

Adjourned. S. E. Tinkham, *Secretary.*

Annual Report of the Board of Government for the Year 1900-01.

Boston, March 20, 1901.

To the Members of the Boston Society of Civil Engineers:

In compliance with the provisions of the Constitution, the Board of Government submits its report for the year ending March 20, 1901.

At the last annual meeting the total membership of the Society was 490, of which 482 were members, 2 honorary members and 6 associates. During the past year we have lost 9 members; 2 by death, 5 by resignation and 2 by forfeiture of membership for non-payment of dues.

There have been added to the Society during the year 19 members, 17 of these have been new members and 2 former members have been reinstated.

Our present membership consists of 2 honorary members, 6 associates and 492 members; a total of 500.

The record of the deaths during the year is: John C. Haskell, died June 12, 1900; Moses W. Oliver, died September 8, 1900.

Ten regular meetings and one special meeting of the Society have been held during the year, and the nineteenth annual dinner was given at the Hotel Vendome on March 5, 1901.

The average attendance at the regular and special meetings was 74, the largest being 142 and the smallest 45. The attendance at the annual dinner was 149.

The following papers have been read at the several meetings:

March 21, 1900.—"The Outlook for Engineers," by President C. Frank Allen.

April 4, 1900.—"The Evolution of the Modern Sky-scrapers," by Clarence H. Blackall. (Illustrated.)

April 18, 1900.—"Difficulties Encountered in Building the Concord, Mass., Sewerage System," by Leonard Metcalf. (Illustrated.)

May 16, 1900.—"Automobile Vehicles," by Prof. Louis Derr. (Illustrated.)

June 20, 1900.—"Filtration Experiments made at Pittsburg," by Morris Knowles. (Illustrated.)

September 19, 1900.—An account of matters of interest to engineers seen in Europe during the past summer, by Henry Manley, Edward Sawyer, F. W. Hodgdon, H. D. Woods and Desmond FitzGerald.

October 17, 1900.—"A Successful Siphon," by R. S. Hale. "Experiments on Brick and Concrete Arches," by W. D. Bullock. "Tests of a Rapp Floor and a Gustavino Arch," by F. H. Fay. "Expanded Metal in Connection with Concrete Construction," by W. M. Bailey. "Ransome System of Concrete Work," by M. C. Tuttle. "The Roebling System," by A. W. Woodman. (Illustrated.) Memoir of John H. Blake.

November 21, 1900.—"The Use of Water Power by Direct Air Compression," by W. O. Webber. (Illustrated.)

December 19, 1900.—"Stone Arch Bridges Recently Constructed on the Fitchburg Railroad," by A. S. Cheever. "Arch Centers," by J. W. Rollins, Jr. (Illustrated.)

January 23, 1901.—"Palaces on the Grand Canal," by Desmond FitzGerald. (Illustrated.)

February 20, 1901.—"Submerged Pipe Crossings, on the Metropolitan Water Works," by C. M. Saville. (Illustrated.)

Five informal meetings have been held in the Society's library during the past year. The subjects discussed at these meetings have been as follows:

March 28, 1900.—"A Year in Alaska," by Laurence B. Manley.

April 11, 1900.—"Improvement of Feeder to Middlesex Canal," by Arthur T. Safford.

December 5, 1900.—"Street Construction as seen in the Streets of London, Paris and other European Cities," by Henry Manley. Also, "Description of the Pitch Lake in Trinidad," by H. T. Manley.

January 2, 1901.—"Methods of Mixing Concrete," by Sanford E. Thomson.

January 9, 1901.—"Some Impressions of Manila," by J. C. S. Taber.

The board desires to congratulate the Society upon its growth in strength, both numerically and financially, and to call its attention to the fact that our charter only allows us to hold real and personal estate to the amount of $20,000, while at the present moment the property of the Society is worth not far from $15,000.

In order to meet the contingencies of a bequest, or a movement in the direction of securing permanent quarters and of the possible delays in obtaining the necessary legislation to hold a larger amount, the retiring board recommends that the incoming one be authorized and directed to make application to the next session of the General Court for the right to hold real and personal estate to the amount of $100,000, or such other amount as that board shall deem advisable.

The growth of our Society is nowhere more apparent than in the congested condition of our Library, which needs much additional wall and floor space for the material we have, and at the same time should be greatly strengthened in standard engineering literature. To make room for the new books it would seem best to send away for storage, until we have more room, or otherwise dispose of such material, which can be very nearly, if not quite as well consulted at the public libraries.

Two years since the Society adopted the policy of appropriating $50 annually for the purchase of standard engineering books. It now being apparent that that step was a judicious one, and it being also clear that $50 annually is not sufficient to provide the new books which we should have,—and many of the older ones which we have not as yet been financially able to get, but cannot afford to be without,—the board recommends that the appropriation for this purpose be increased to $75 for the coming year.

We desire to call to the favorable attention of the Society the practice the past year, adopted by the Excursion Committee, of causing to be printed upon the notices of the monthly meetings information relating to engineering work in progress in this part of the country, and to express the opinion that it should be continued.

Respectfully submitted to the Board of Government,

Alexis H. French, *President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1900-01.

Current Fund.

Receipts:		
Dues from new members	$95.00	
Dues for year 1899-1900	13.00	
Dues for year 1900-01	3,389.00	
Dues for year 1901-02	29.00	
Sales of Journals	2.10	
Rent of rooms	900.00	
Interest on deposits	23.77	
Balance on hand, March 22, 1900	1,910.43	
		$6,362.30
Expenditures:		
Rent	$1,665.00	
Association of Engineering Societies	1,004.50	
Transferred to Permanent Fund	2,017.50	
Printing, postage and stationery	469.04	
Secretary salary	400.00	
Furniture and repairs	117.63	
Periodicals and binding	96.70	
Incidentals	97.17	
Annual dinner	85.50	
Books	49.60	
Stereopticon at meetings	80.00	
Lighting rooms	26.34	
Clerical work for Librarian	21.49	
Reporting meeting	5.00	
		$6,135.47
Balance on hand		$226.83

Permanent Fund.

Receipts:		
Seventeen entrance fees	$170.00	
Current fund	2,017.50	
Shares Merchants' Co-operative Bank	1,147.18	
Interest	225.30	
Subscription to Building Fund	100.00	
Balance on hand, March 22, 1900	165.54	
		$3,825.52
Expenditures:		
Deposit in Franklin Savings Bank	$1,017.50	
Deposit in Provident Institution for Savings	37.35	
Deposited in Boston Five-cents Savings Bank	39.74	
Deposit in Eliot Five-cents Savings Bank	1,053.41	
Deposit in Warren Institution for Savings	31.16	
Deposit in Institution for Savings in Roxbury	27.64	
Shares in Merchants' Co-operative Bank	586.71	
Dues on shares, Merchants' Co-operative Bank	308.00	
Dues on shares Workingmen's Co-operative Bank	300.00	
Dues on shares Volunteer Co-operative Bank	300.00	
		$3,701.51
Balance on hand		$124.01

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 20, 1901.

One Republican Valley R. R. bond (par value)	$600.00	
25 shares Merchants' Co-operative Bank	1,541.40	
25 shares Workingmen's Co-operative Bank	2,048.00	
25 shares Volunteer Co-operative Bank	1,992.00	
Deposited in Provident Institution for Savings	1,177.69	
Deposited in Boston Five-cents Savings Bank	1,165.99	
Deposited in Eliot Five-cents Savings Bank	1,053.41	
Deposited in Warren Institution for Savings	1,039.91	
Deposited in Institution for Savings in Roxbury	1,027.64	
Deposited in Franklin Savings Bank	1,017.50	
Deposited in Old Colony Trust Company	124.01	
		$12,787.55
Amount belonging to Permanent Fund March 21, 1900		10,010.38
Increase during the year		$2,777.17

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund	$12,787.55
Current Fund	226.83
	$13,014.38
Total amount March 21, 1900	11,920.81
Total increase during the year	$1,093.57

Report of the Committee on Excursions.

Boston, Mass., March 20, 1901.

To the Members of the Boston Society of Civil Engineers:

Your Committee on Excursions presents the following report for the year 1900-1901:

Twelve excursions have been made during the year.

April 18, 1900.—To the Charlestown Bridge, and to inspect the Pneumatic Carrier System between the Union Station and the Post Office, Boston. Attendance, 25.

May 16, 1900.—To the Boston Navy Yard, and the Hoosac Tunnel Docks, both at Charlestown. Attendance, 140.

June 20, 1900.—To the work of Abolition of Grade Crossings at Congress street; the Commonwealth Dock; and the Metropolitan Coal Company's coal handling plant, all in Boston. Attendance, 22.

July 18, 1900.—To the Fore River Engine Works, Weymouth. Attendance, 103.

August 22, 1900.—To the sources of supply, New Bedford and Taunton Water Works, Lakeville, Mass. Attendance, 25.

September 19, 1900.—To the Cape Ann Quarries and Breakwaters, Rockport, Mass. Attendance, 35.

October 17, 1900.—To the Wachusett Dam and Reservoirs, Metropolitan Water Works, Clinton, Mass. Attendance, 47.

November 21, 1900.—To the Boston Elevated Railway. Attendance, 80.

December 6, 1900.—To the Cunard steamship "Saxonia." Attendance, 62.

December 19, 1900.—To the New England Electric Vehicle Transportation Company's plant, Boston. Attendance, 22.

January 23, 1901.—To the factory of the Derby Desk Company, Somerville. Attendance, 4.

February 20, 1901.—To the plant of the United States Steel Company, West Everett. Attendance, 30.

Total attendance, 595; average, 50.

This total attendance of 595 compares very favorably with the record of 550 for the preceding year, and 600 for the year before that, the latter being the highest figure ever attained.

Besides the regular work of planning and conducting excursions, your committee has begun the publication of a monthly "Bulletin of New Engineering Work," with the idea of furnishing the necessary information to enable individual members to visit work in which they may be particularly interested. Seven issues of the Bulletin have been published, besides one special bulletin.

There is a cash balance of $22.54 in the hands of the committee.

Respectfully submitted,

A. B. Corthell,
Charles W. Sherman,
D. L. Turner,
John R. Burke,
Committee on Excursions.

Report of the Library Committee.

Boston, Mass., March 20, 1901.

To the Members of the Boston Society of Civil Engineers:

The Committee on the Library makes the following report for the year 1900-1901: 217 volumes and a number of pamphlets have been added to the library. The highest accession number is 4529. This number, however, does not correctly represent the number of volumes in the library, as, in past years, pamphlets have sometimes been entered in the accessions book.

The following engineering text-books, having been approved for purchase by the Board of Government, were bought at an expense of $49.60. Those marked with a star were approved by the Board of Government of the preceding year, but were not then purchased on account of the insufficiency of the appropriation.

List of Text-Books Bought, 1900-01.

Herschel: Frontinus and the Water Supply of the City of Rome."
Wegmann: "Design and Construction of Dams."
Christie: "Chimney Design."
**Engineering News:* General Index, 1890-99.
Wolff: "Windmill as a Prime Mover."
Goodell: "Water Works for Small Cities and Towns."
*Ganguillet & Kutter: "Flow of Water in Channels," tr. Trautwine.
Tillson: "Street Pavements and Paving Materials."
Wilson: "Topographic Surveying."
Wait: "Law of Operations Preliminary to Construction."
*Pryde: "Chambers's Tables."
Woodhead: "Bacteria and their Products."

Howe: "Retaining Walls."

*Kent: "Mechanical Engineer's Pocket Book."

*Campbell: Manufacture and Properties of Structural Steel."

Howe: "Arches."

Engineering News: "Piles and Pile Driving."

Early in the year the Board of Government requested from the Library Committee a report on the question of "What ought to be the general policy of the library in the acquisition of books, especially in the purchase of reference and text-books?" and "What additional periodicals, if any, ought to be subscribed for?" Reports on these questions were submitted in the course of the year, and are recorded in the minutes of the Board of Government. The recommendations are in substance as follows: The general policy of the library ought to continue as hitherto, a specialty being made of State and Municipal reports that are of engineering interest, but more attention ought to be given to engineering text and reference books. An annual expenditure of about $75 for such books was advised.

On the question of additional periodicals a list was presented, all but two of which were subsequently approved by the Board of Government, and were added to our table. The following periodicals and society publications are now regularly received and placed on our table. Those marked with a star are not preserved and bound.

American Architect.

**American Gas-Light Journal.*

American Institute of Electrical Engineers, transactions..

American Institute of Mining Engineers, transactions.

American Society of Civil Engineers, transactions.

American Society of Mechanical Engineers, transactions.

**American Trade.*

Association of Engineering Societies, journal.

Canadian Society of Civil Engineers, transactions.

Cassier's Magazine.

Deutsch-Amerikanischen Techniker-Verband, Mitteilungen.

Electrical World.

Engineer (London).

Engineering (London).

Engineering and Mining Journal.

Engineering Magazine.

Engineering News.

Engineering Record.

Engineers' Association of the South, proceedings.

Engineers' Club of Philadelphia, proceedings.

Engineers' Society of Western Pennsylvania, proceedings.

Forester.

Franklin Institute, journal.

Indian Engineer.

Institute of Mechanical Engineers (London), proceedings.

Institution of Civil Engineers (London), proceedings.

**Iron Age.*

**Irrigation Age.*

Liverpool Engineering Society, transactions.

**Marine Engineering.*

Master Car Builders' Association, proceedings.
**Municipal Engineering.*
New England Water Works Association, journal.
Nova Scotia Institute of Science, proceedings and transactions.
Ponts et chaussees, Annales des.
Railroad Gazette.
Société des Ingénieurs Civils, memoires.
Street Railway Review.
Technology Quarterly.
Technology Review.
United States Naval Institute, proceedings.
**United States Patent Office Gazette.*
University of Wisconsin, bulletin.
Verein deutcher Ingenieure, Zeitschrift.
Western Society of Engineers, journal.
Worcester Polytechnic Institute, journal.

Besides the usual accessions of government, state and city reports, several notable accessions by gift have been received. The Massachusetts Topographical Survey Commission has made our library one of the places of deposit for the atlases of the Town Boundary Survey, and 35 atlases have been received. From M. Eiffel have come two sumptuous volumes, a description and illustrations of the Tower of 300 Meters. From our Past President, Desmond FitzGerald, we have 7 volumes of *London Engineering* and 8 volumes of Spon's Engineering Dictionary. Mr. FitzGerald's gifts arrived too late to be accessioned before the annual meeting, and are not included in the 217 volumes mentioned at the beginning of this report, nor are the 50 volumes of the *Zeitschrift für Bauwesen,* the gift of our Past President Clemens Herschel. These were given under the condition that they should be kept together and marked with the donor's name, and not borrowed from the library. These conditions were accepted by the Board of Government on March 16.

Towards the end of 1900, practically the whole of our shelf room was filled, leaving no space for the expansion of our library or for that of our subtenants, the Water Works Association, and it became necessary to provide additional room. A new bookcase was constructed at a cost of about $75, against the west wall, beside and over the little window. This gives about 76 lineal feet of additional shelving. To make this available for the expansion of each of the ten sections of the library, it was necessary to rearrange nearly all the books. This was done, and after giving up about 37 lineal feet of shelving for the use of our tenants we have left for ourselves (by putting a number of the less used books in the rear rank), sufficient room for the normal growth of about three years.

Shelf lists of certain of the municipal reports have been made by Mr. Bryant, and shelf lists of the State reports have been begun by Mr. Flinn and the Librarian.

Throughout the year a large number of duplicate copies of periodicals have encumbered the room. Negotiations have been in progress for a storage within the building, but so far no satisfactory arrangement has been arrived at. If no convenient storage place can be found, it will become a question whether it would not be better to dispose of all the bulky duplicates. While this store of duplicates is an occasional convenience to our members, so

that $4.10 worth have been sold in the course of the past year, yet the encumbrance and disfigurement of the library is a high price to pay for this occasional service. The present periodical rack is not convenient. It cuts off the light from the further side of the table, and it is not easy to keep in order. We recommend to our successors that they study means for the more convenient storage of the current periodicals. Another question which we bequeath to our successors is that of certain reports that contain but little matter of engineering interest. In view of the lack of room, it seems doubtful whether it is wise to continue to receive such reports, or even to keep on the shelves those volumes that we already have.

Respectfully submitted,

LOUIS F. CUTTER, *Chairman,*
FREDERIC H. FAY,
FRANK P. MCKIBBEN,
of the Committee on the Library.

REPORT OF THE COMMITTEE ON QUARTERS.

BOSTON, March 20, 1901.

To the Boston Society of Civil Engineers:

The Committee on Quarters have examined several pieces of property during the past year, with reference to purchase, but have been unable to find a lot which will not involve the expenditure of a large amount of money to adapt it to the needs of the Society.

As the lease for the present quarters in Tremont Temple expires on May 1, 1902, and our library is already crowded, it seems to your committee that some steps should be taken during the present year towards securing a house for the Society. This will probably involve the expenditure of about $80,000. From the report of the Treasurer, it appears that we now have $12,787.55 in the treasury.

There are several societies in Boston which, like our own, are looking for permanent quarters. The most feasible scheme for building, without encumbering the Society with a heavy debt, seems to be to unite with several other societies, if such can be found, and erect a building to be used in common.

If a movement in this direction appears to be desirable, your committee intend to make at once an effort towards securing the co-operation of some other societies.

Respectfully submitted,

DESMOND FITZGERALD, *Chairman.*

Civil Engineers' Club of Cleveland.

ANNUAL ADDRESS OF THE PRESIDENT.

THE work of a scientific or technical society is, I take it, of a threefold nature: to keep alive the idea of the professional life; to establish cordial relations between the several members of the different professions represented; and to furnish a means for the spreading of the results of the latest researches amongst the members.

Without having planned to arrange the work of the year under these heads, it may be fairly described under some such classification.

With great earnestness on the part of the Membership Committee of the year just closing, and of the same committee of the year preceding,

the men of the city in the different professions represented have been sought out and invited to affiliate themselves with our Society. The idea has been to band together in one society having proper central headquarters all men associated in several lines of work. It has been hoped that by persistent work nearly every man so engaged could be induced to feel that the professional aspect of his work could best be fostered by being with us in the work we have set ourselves to do. So many men on leaving college find, in due time, their proper sphere of usefulness and, before they know it, are in a rut. They do their day's work and go home. They may take one technical journal and even go so far as to conscientiously read it. But from the fact that their daily work is so constant, and perhaps fatiguing, they straightway forget (so it often seems as you observe them) that they are technically educated; that they are professional men as opposed to business men; that they have to do with creative technical problems rather than the sale, manufacture or transfer of some commodity. Soon they drop out of the Alumni Club of their college, take little interest in the theoretical part of their life work, and plod along, doing the best they can in the environments more or less unideal which surround us all in our daily work.

To belong to a profession is a privilege. It may or may not be as remunerative as many lines of business. That is neither here nor there. The man should feel that he would rather follow it than engage in any other work—money or no money. In a sense the engineer should be made from the man who is good for nothing else; or, putting it the reverse, he should be good for engineering or architecture and for nothing else. To such an one the daily work is only a part of the pleasure of being of the profession he represents. To take pride in the great works and achievements of others laboring in the same field, which represent not so much money earned by the engineer as great mental power and genius,—this is one of the emoluments of the profession. To keep in touch with great feats of the mind, great conquering of mind over matter, and to feel that *we* are a part of the same profession, contributing our conscientious daily labor toward the progress of the world,—all this should be one of the distinct aims of any man, I believe, in following a chosen technical line. In some measure this can be accomplished by the individual working and thinking alone. But we believe that being a member of our Society, and receiving our journal and attending our meetings, tends to keep warm in a man's heart the thought that he had when as a student at college,—he warmed toward the other fellow, because he was of *his* course, studying *his* special studies, bright in *his* own lines of thought, full of the same aspirations in life. We are here of one mind. We believe in the work of others greater than ourselves, and in this we find comfort. We are proud of our vocation, and we encourage each other in this idea that in the professional life we have some ideals and thoughts not common to the business life.

Through the endeavors of the Membership Committee the Club has increased its roll by thirty-eight new names during the past year, thus making the largest advance in the Club's history.

The second division under which I would speak of the work of the year is that of establishing and cultivating cordial relations between the men allied to each other directly or indirectly, and whose names are upon our rolls.

This is certainly a very worthy work. I fancy that technical men become reserved in manner more often than the men of what we might term the talking professions, such as law, medicine and the ministry. While it probably is not fair to say that the engineer does more thinking than the lawyer or the minister, he certainly does do less talking. To acquire a habit of much thinking and little talking is, I think, on the Darwinian theory, to render the individual less prone to talk easily and freely and more and more likely to confine himself more and more closely to the daily task,—letting his relations with his fellow practitioners grow less and less cordial, until he finds himself almost alone in his work. Companionship of the right sort of men in the same line is uplifting. It is encouraging. It is sweetening. Nothing so dispels the professional jealousies as this companionship in a cordial society. The rivalries of life tend to separate men. In the business life it is what is termed competition, meaning generally a war over price. In the technical professional life it is a mental comparison more often—a silent battle of mind against minds, which is none the less acute because the men are reserved. Our club life has for one of its main objects the breaking down of all these barriers. It aims to have its men frankly know each other better, and as they learn how free from bitterness and even envy and conceit the other is, they feel kindlier toward all and more hopeful. I believe the saying, "Come with us and we will do you good," is a truthful remark and represents at least our best wishes toward the men devoted to the technical professions in Cleveland. An especial effort has been made this year to make the meetings attractive from the social point of view. When we were in the Case Building we had to adjourn to a restaurant in order to have a social gathering after the literary part of the program. With our new rooms it has been possible to have a delightful lunch served immediately after the meeting itself, during which time we have had rare opportunities to become acquainted and to welcome visitors and strangers. I am sure we have enjoyed those meetings. The new member has found it much easier to know and be known by the men attending. I trust that in the new year this social feature will be introduced where feasible.

A third division of the work, and really one of the greatest importance, is the furnishing the means of spreading the results of the latest researches amongst the members. The business man withholds the secrets of his business to a great degree from his competitors. The professional man considers it in a great measure unprofessional to keep to himself advance work in his own line of study. And is not this one of the great distinctions between the business and professional life? And does it not indicate a breadth of thought, a sweet giving to others the results of many years it may be of careful work. It is a matter of which the medical profession should be proud, that, no sooner does a surgeon or physician discover a new method or treatment than straightway he publishes it. His gain is professional honor and recognition. His financial reward is only indirect.

And I believe that the professional man so guiding his career is *himself* more the gainer than he is the loser. It is generous to give freely; but in the giving one becomes, I believe, more sensitively appreciative of the results of others' study. It is not an ill bargain one makes with the world to thus give. I think those who have thus given to our Club of

their best thought and experience feel as I do. We should foster this spirit. Fine rooms are splendid accessories, but they are *only* accessories. The *real* thing is the work of the brains represented. Even the social life is second to that. As professional men, we are professional thinkers and incidentally doers. But the doing is easier than the thinking in most cases, and in all cases the thinking is the result of the finer quality of the mind.

To encourage fine technical thinking is a worthy object. And our Club is certainly doing much to fulfill its mission if it shall encourage to the utmost all advanced thinkers. It furnishes a place where they can deliver their views and, through the use of its journal, spread the subject matter before men of many cities. This work has been in the hands of a Program Committee, of which Mr. Green is chairman, which has had entire charge of the literary part of the year's work. I will not refer in detail to their work. It has seemed admirable, and I wish publicly to thank them for thus upholding the officers of the year in so signal a manner. There is much missionary work which might be done still, and especially amongst the new members. With the larger membership comes a larger field for the Program Committee. The literary part of the Civil Engineers' Club, I therefore prophesy, is to grow better and broader from year to year.

The having of fine rooms has made it possible to entertain the ladies in our rooms. This might properly be made a feature of the work. To an extent of which the outside public are hardly aware, the wife of a technical man knows and feels more or less of the daily work of the husband. To invite the ladies to occasionally listen to our papers would, it seems to me, be the means of assisting them to more fully appreciate their husbands' work. When we think of Mr. Roebling's wife assisting him in his great undertaking at his bedside, we realize what, in extreme cases, the wife might do. At least to encourage their coming, and, coming, too, at stated times, to hear of engineering matters, is a matter I should like to see tried. If, at such a time, we all made it a point to bring our wives, I am sure they would vote the evening a success. We held one such meeting at Christmas time, and it was a success from every point of view. I wish we might decide at least to have a ladies' night at the holidays and make it a feature of the year.

One more matter I shall speak of, and then I am done. The library of the Club has been brought over to our rooms and an extra room rented and the libraries of all the societies housed there together. This is a most important advanced step and, I trust, will be the means of the books being more used than they have been. A new step has been taken also in this connection, and by one of our own members,—Mr. Searles. He has very generously donated a valuable collection of technical books to the Club.

Would it not be possible to get the several members of our Society to give a book now and then to the Club's library? I mean, a book from their own private shelves. A book perhaps well worn (that will prove its value): perhaps with side notations or its pages indicating that its owner was alive and thinking. I think that each year quite a number of books could thus be added and would prove invaluable. And especially might it be practical to urge that the men about to retire ever have in mind that

our library is a better place for technical books than some garret or upstairs hall, as is the fate of so many professional books,—whether on engineering, architecture, medicine, law or religious subjects.

In connection with the library, one other thought comes to me: Would it not be possible to make it a circulating library and thus make the books do a much larger work? Of course, only one copy of a work is on our shelves, and it therefore might be out when called for. But when we consider how seldom *any* book is called for under the present system, it would not seem to be taking very great chances. Of all the library rules which work hardship in both of our public libraries, that which forces the patrons to stay in the rooms in order to use the reference books is the greatest. It may be necessary, although I should doubt it; but certainly very, very few ever use the reference books as a result. It would be better to lose a book now and then, and feel that the rest were filling a great want, than to debar so many from their use. A tired man is a poor one to go several miles after dinner to a reference library unless he is obliged to, and who of us can take the time in daylight to spend there? In our own little library, would it be sacrilege to allow our books to go out under some simple system? Say for a week only, with power to renew for one week if no card is deposited for it? I believe it would in this way fill in a want which the two great libraries seem unable to meet.

I cannot think but that our members would appreciate it and would soon consider it as one of the good things about our Club. I would respectfully suggest that this matter be brought up by the new board and Librarian and ways be provided to bring it about.

Gentlemen, the task of the officers you elected a year ago is done. For your kindness and forbearance during the year we thank you. For your support we shall ever be grateful. And we trust that, as the years pass on, the Civil Engineers' Club of Cleveland will grow stronger and stronger, more and more honorable and efficient, until our Club will be counted one of the strong, wholesome, uplifting institutions of our beautiful Forest City.

Secretary's Report.

During the year the Club has held ten regular meetings, eight semi-monthly and three receptions.

The average attendance for the regular meetings has been 24 members and 9 visitors; for the semi-monthly meetings 19 members and 7 visitors.

The membership on March 1, 1900, consisted of 5 honorary members, 22 corresponding members, 20 associate members and 133 active members, a total of 180.

During the year we have lost by death Messrs. Roswell H. St. John, Henry M. Claflin and Joseph T. Talbot, all active members.

Eight members, four corresponding, three active and one associate, have resigned and one active has been dropped.

Forty-seven active members, one associate member and one corresponding member have been elected. These changes during the year left, on March 1, 1901, 5 honorary members, 19 corresponding members, 20 associate members and 174 active members, a total of 218, showing a net gain of 38 members over the list of March 1, 1900.

FINANCIAL STATEMENT.

BALANCES ON MARCH 1, 1900.

Permanent Fund	$915.55
General Fund	311.84
Library Fund	173.74
	$1,401.13

RECEIPTS, MARCH 1, 1900, TO MARCH 1, 1901.

Dues	$1,728.00
Fees	240.00
Library Subscriptions	15.00
Refunded Postage	.60
Western Cement Co. (Journal)	3.00
Advertising Commission	70.20
Interest	39.58
	$2,096.38

EXPENSES.

Periodicals	$30.65
Printing	174.72
Salaries	200.00
Postage and Express	61.70
Stationery, etc	17.68
Books	59.27
Journal	387.75
Rent	692.00
Certificates	12.00
Social Account	328.16
Case Library	75.00
Furniture	23.25
Flowers	10.00
	$2,072.18
Net receipts	$24.20

BALANCES ON HAND MARCH 1, 1901.

Permanent Fund	$1,195.13
General Fund	100.73
Library Fund	129.47
	$1,425.33

Arthur A. Skeels, *Secretary.*

Report of the Librarian.

Your Librarian regrets that, owing to his absence from the city during nearly the whole year, he has been unable to devote as much time to the library as he would gladly have done, and at the same time he wishes to express his gratitude for the valuable assistance of our former Librarian, Mr. A. Lincoln Hyde, who has acted in the writer's place during his absence. Through Mr. Hyde, arrangements were made for the transfer of the Club's library from its old quarters in Case Library

to our new rooms in the Associated Technical Clubs, the matter having been duly proposed at a meeting of the Club and authorized by its vote.

Cases for the library were ordered several months ago, but, owing to delay in their completion and shipment, they have only just been received, and within the last week the greater portion of the books comprising our library have been put in place in them. The cases which were gotten for these books were purchased with money appropriated from the general treasury of the Club, and not from the special library fund, in order that the latter might be kept intact for the special purpose for which it was given. One reason which made it desirable to transfer the library at this time was that the subscriptions which were inaugurated five years ago to this fund have just been completed, and further, the agreement between the Case Library and ourselves, by which they were, during this same period, to appropriate for the purchase of engineering works an equal amount of money to that expended by the Civil Engineers' Club, has also terminated. Regarding this private subscription, while there are still some who are not as yet amenable to the persuasion of your Library Committee and are still in arrears as to their last payment, yet there is but a comparatively small sum outstanding as coming from those of whom we can expect payment, and the original list has been considerably depleted by death or removal from the city. In fact, it was the observation of your Committee that those who most earnestly and generously contributed to this fund, judging as one may from outward appearances, could hardly be classed among the members *best* able to carry this burden; and your Committee would therefore respectfully recommend, in view of the termination of these subscriptions and under the present good financial standing of the Club, that an appropriation for the library be made from the general treasury, so that the burden may come more evenly on the whole membership than has heretofore been the case.

Through the generosity of one of the members of the Club, who always has had its interest at heart, we have been brought into the possession of some two hundred engineering volumes of great interest, and in behalf of the Club your Committee would again gratefully acknowledge this gift from Mr. W. H. Searles, past president of the Club. Besides important civil engineering works, there will be found among the books given by him valuable contributions on the subject of the Great Pyramid, Transactions of the Antimetric Society, etc. Mr. Eiffel, the famous engineer and promoter of the great tower which bears his name on the Champ de Mars in Paris, has presented to the Club three most valuable works, covering a complete history of the design and erection of that great triumph of engineering work.

Your Committee believes that the transactions of the various technical societies in which the members of our Club are interested are of special value to our library, since, in these transactions, the engineering topics of the day are best discussed from year to year, and since such transactions are not as easily found or procured by those who are possessed of private libraries as are the individual treatises on these same subjects, and it therefore gives us pleasure to state that we have, on our shelves, complete to 1893 and 1896, the Transactions of the American Society of Civil Engineers, the Transactions of the American Society of Mechanical Engineers nearly complete, and it is needless to say that we

would be greatly indebted to any of the members of our Club who may be members of either of these societies, and who might feel disposed to give us the few remaining numbers.

For some time we have been favored with the reports of the Chief Signal Officer, the War Department, the Secretary of War, etc., so that the Club now has 245 volumes of these reports. At the present time there is not enough room in our library to give them place, and they have therefore been stored away where they can be gotten at more or less readily, and, if considered important and if our quarters will permit, arrangement will be made later for still more easy access to them.

The Club has subscribed for a number of periodicals of literary interest for the reading room of the Associated Technical Clubs, but these periodicals have been paid for from the funds of the Club and not from the library fund.

In anticipation of the change from the Case Library to our present quarters, and in view of the fact that we had, while there, the advantage of so many engineering works which are not the property of our Club, your librarian deemed it advisable to allow part of the money collected to remain with the treasurer unspent, so that it might be used at such a time as the present for purchasing books similar to those now in the possession of the Case Library, and the end of this fiscal year therefore finds us with somewhat over $129.47 which can be used for this purpose.

Your Committee would gratefully acknowledge the kind interest of Dr. Howe, member of the Library House Committee, as well as Mr. A. Lincoln Hyde for valuable assistance in our work. We believe that the removal of the library to its present quarters will be of great advantage to the Club and that the prospects for the coming year are brighter than ever for those who are interested in our technical library.

Respectfully submitted,

WM. E. REED, *Librarian.*

The papers during the past year have been more than usually interesting and instructive and of such variety of subjects as to interest all.

Although two papers per month were prepared for the spring and early summer of 1900, it was not expected to hold regularly two meetings per month. In October, however, it was decided that two meetings would be desirable, and from that time the Club has met and listened to a paper twice each month.

The stereopticon has been freely used during the year and has proved a valuable feature and a great aid. Of the sixteen papers presented, eight have been illustrated by slides.

During the summer months of July and August, 1900, no meetings were held, but an outing at Beach Park on July 21 was thoroughly enjoyed by a large number.

The second meeting in December, occurring regularly on Christmas evening, was postponed until the evening of December 28 and a special Christmas entertainment prepared. These special gatherings of a social nature should be encouraged. One of the greatest needs of our Club is a closer social relationship and a wider acquaintance among the members, and there can be no better way to promote this than by occasional good times together. The regular meetings do not seem to cultivate this social spirit to a sufficient degree.

It was suggested a year ago that a question box be established, wherein questions for discussion by members of the Club could be placed by any member. No material box was provided, but it was announced that any questions addressed to the Club through its Secretary or through the Program Committee would be promptly brought before the Club for discussion. The members have not availed themselves of this feature to any alarming degree. In fact, two questions, propounded by the same interrogator, have been the sole fruit during the year.

It was also suggested that possibly papers would be more varied in interest, and might be easier of preparation if they were made shorter, and two subjects were taken up at each meeting. The fact seems to be, however, that any one preparing upon any topic finds, when he has gathered his data, that the difficulty is in concentrating it to a sufficient degree, and the necessity seldom arises for increasing the length or scope of a paper or topic.

Respectfully submitted,

BERNARD L. GREEN, *Chairman.*

TREASURER'S REPORT.

RECEIPTS.

Cash on hand March 1, 1900:		
Permanent Fund	$915.55	
General Fund	311.84	
Library Fund	173.74	
		$1,401.13
Received from Secretary on account of Permanent Fund	$279.58	
" " " " " " General Fund	1,801.80	
" " " " " " Library Fund	15.00	
		2,096.38
		$3,497.51

DISBURSED.

Secretary's vouchers on account of General Fund, Nos. 101 to 156, inclusive	$2,012.91	
Secretary's vouchers on account of Library Fund, Nos. 22 to 32, inclusive	59.27	
		2,072.18
CASH ON HAND FEBRUARY 28, 1901.		
Permanent Fund	$1,195.13	
General Fund	100.73	
Library Fund	129.47	
		1,425.33
		$3,497.51

JOHN N. COFFIN, *Treasurer.*

Engineers' Club of St. Louis.

522D MEETING, MARCH 6, 1901.—Held at 1600 Lucas Place at 8.15 P.M.; Vice-President Kinealy presiding.

Attendance, twenty-five members and nine visitors.

Minutes of the 521st meeting were read and approved with corrections.

Minutes of the 306th meeting of the Executive Committee were read.

A communication from the Finance Committee of the Public Welfare Commission, requesting a subscription by the Club of $100 toward the ex-

pense of the commission, was read. The Executive Committee, having considered the matter, recommended that the objects of the Club did not warrant the Club to make an appropriation of this character, but that it would be well for the members of the Club to give the commission their assistance as citizens. Motion was passed to adopt the recommendation of the Executive Committee.

The members of the Board of Managers having reported to the Executive Committee a plan whereby advertisements for the JOURNAL and *Bulletin* would be solicited by an agent to be employed on a commission basis, the Executive Committee recommended that the Club give the members of the Board of Managers full power to put said plan into operation. Motion was passed to adopt the recommendation of the Executive Committee.

Messrs. W. H. Henby, Truman M. Post and Louis Bendit were elected to membership.

The subject of the evening was an informal address on "The Development of the Steam Engine," by Prof. J. H. Kinealy. The speaker gave a very interesting talk, fully illustrated by lantern slides, and he reviewed the various forms of engines from the earliest known down to the latest developments.

Discussion was participated in by Messrs. Ockerson, Bryan, Van Ornum, Borden and Humphrey.

Mr. Maltby, for the Committee on Lantern, reported they had bought a reading lamp for the meeting room, and a new lamp for the lantern, and had contracted for the necessary direct current for the lamp.

Motion was carried to ratify the action of the Committee on Lantern.

For the next meeting announcement was made of a paper by Mr. S. Bent Russell, principal assistant engineer, water works extension, on "Bank Revetment Work at the Chain of Rocks Pumping Station," illustrated by lantern slides.

Adjourned to an adjoining room, where lunch was served.

W. G. BRENNEKE, *Secretary.*

523D MEETING, MARCH 20, 1901.—Held at 1600 Lucas Place at 8.20 P.M.; President Spencer presiding.

Twenty-four members and four visitors were present.

The minutes of the 522d meeting were read and approved.

Mr. Flad, Chairman of the Committee on Lantern, submitted the formal report of the committee to the Club. As the committee had reported at the previous meeting and a motion carried to ratify the action of the committee, no action was taken at this meeting on the report.

Professor Van Ornum was then requested to take the chair, and President Spencer addressed the Club in behalf of the Public Welfare Commission, explaining in detail the objects and needs of the commission, its relation to the Engineers' Club, and the work it had so far accomplished. After President Spencer resumed the chair, Professor Van Ornum moved, and it was duly seconded, that the Executive Committee be empowered to take action looking toward the subscription, by the Club as individual members, to the amount desired by the commission. Mr. Flad moved as a substitute that the Executive Committee be directed to pay the $100 assessed against the Engineers' Club out of

the Entertainment Fund. Mr. Bouton objected, as this was a trust fund, and he thought its use was restricted. Mr. Wheeler stated that the American Society of Mechanical Engineers turned this fund over to the Club in trust without any restrictions. After considerable discussion, Mr. Flad's motion was voted upon and carried.

The subject of the evening was an informal address by Mr. S. Bent Russell on "Revetment of River Bank at the Chain of Rocks by the St. Louis Water Department." Maps and general plans were exhibited showing the conditions and scheme of construction. Lantern slides were also exhibited, showing the progress of the work at different times, the plant used in the work, etc. The work is estimated to cost when complete about $80,000, and has extended over a period of about four years. The bank protected is about 6000 feet long and from 25 to 30 feet in vertical height. The points of greatest interest are the use of gravel concrete in the place of the usual rip-rap on the upper bank, and the method used to prevent the revetment being undermined at the toe of the slope where the work rested on soft material. These methods include rip-rap dikes, brush mattresses, and aprons made of sawed lumber bound together with wire cable and sunk with rip-rap. Another point of interest is the treatment of the bank where it showed a disposition to slide or slough off.

Discussion followed by Messrs. Maltby and Turner.

For the next meeting announcement was made of a paper by Mr. Louis Bendit on "Treatment of Feed Water for Boilers."

Adjourned to library room, where lunch was served.

E. B. FAY, *Secretary pro tem.*

Technical Society of the Pacific Coast.

REGULAR MEETING, MARCH 1, 1901.—Called to order at 8.30 P.M. by President Marx.

The minutes of the last regular meeting were read and approved.

Mr. Chas. M. Kurtz read a carefully prepared paper before the Society, embodying a "Review of the Various Methods of Concrete and Iron Construction used during the Last Decade," which subject was discussed at length by Messrs. Keating, Wing, Prutzman, Wagoner and others.

Meeting thereupon adjourned.

OTTO VON GELDERN, *Secretary.*

REGULAR MEETING, SAN FRANCISCO, CAL., APRIL 5, 1901.—Called to order at 8.30 P.M. by President Marx. The minutes of the last regular meeting were read and approved.

The following names were added to the membership upon regular count of ballots:

Member—Chas. Albert de St. Maurice, civil engineer, of Eldridge, Cal.

Junior Member—James D. Mortimer, instructor in electrical engineering, University of California.

Associate Member—Milo Hoadley, of San Francisco.

The following name was proposed:

A. S. Riffle, civil engineer, of San Francisco, by D. C. Henny, Otto von Geldern and Adolf Lietz.

Professor Elwood Mead, of the University of California, then addressed the Society on the subject of "Irrigation in California," which was discussed by many members present.

The President suggested that the Technical Society act in conjunction with the Water and Forest Association, and that steps be taken to perfect some action of this character.

A motion was made by Mr. Henny that the Chair appoint a committee to confer with the Water and Forest Association in the work now carried on in this State, and that the President be an *ex-officio* member of such committee, consisting of five members. Motion was carried, and the Chairman announced that he would appoint this committee at the next Director's meeting.

On motion, a vote of thanks was passed by the Society, expressing the full appreciation of its members to Professor Elwood Mead for his courtesy in lecturing on the important subject of "Irrigation in California."

Adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of Cincinnati.

121st Regular Meeting, Cincinnati, Ohio, February 21, 1901.—Dinner was served at 6.15 p.m.

The regular meeting was called to order at 7.15 p.m. Vice-President Bogen in the chair.

There were eighteen members present.

Minutes of the meeting of January 17 were read and approved.

Application for active membership was presented by Mr. A. N. Miller.

On ballots being taken, Messrs. R. J. Devenish and John P. Brooks were elected active members and Mr. Guy M. Gest was elected an associate member.

The committee appointed to prepare memoir of Sherman E. Burke, presented the same, which was ordered received and spread on the minutes of the Club.

Mr. Frank L. Fales read the paper for the evening, on "Water Purification and Sewage Disposal at the Lawrence Experiment Station."

After a short discussion of the subject and a vote of thanks to Mr. Fales for his paper, the Club adjourned.

J. F. Wilson, *Secretary.*

Engineers' Society of Western New York.

Regular Meeting, March 5, 1901.—Meeting called to order at 8 p.m.; the President in the chair. The following members present: Messrs. Haven, Knighton, Knapp, Booz, Fell, Fruauff, Bardol, Tutton, Whitford, Tresise, Rogers, Babcock, Rockwood, Roberts, Weston, Diehl, Kielland, Norton, Buttolph, Vander Hoek, McKeown, Morse and several visitors.

Applications for associate were read from the following: William Franklin and John Feist. It was voted that the applications be approved and letter ballot ordered.

It was moved by Mr. Knighton, and seconded by Mr. Diehl that Mr. Ricker be requested to rewrite his paper on Docks and resubmit it to the Society, and that the paper and discussion be published in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. Carried.

The Executive Board reported that they would send out the following letter to various Engineers, Societies, etc.:

ENGINEERS' SOCIETY OF WESTERN NEW YORK,
975 ELLICOTT SQUARE,
BUFFALO, N. Y., March 12, 1901.

The Pan-American Exposition to be held in this city the present year will offer much of interest to Engineers.

We regret that the plan proposed for a separate engineering exhibit has been found impracticable.

The Engineers' Society of Western New York desires to extend to visiting Engineers every possible courtesy. Its rooms are most centrally located in the Ellicott Square Building. The headquarters of the Exposition, telegraph office, telephone station, restaurant, etc., are in the building.

During the Exposition our rooms will be open during the day, and we extend a most cordial invitation to the members of your Society and all visiting engineers to make use of them while in Buffalo.

Your mail addressed care of "Engineers' Society of Western New York, No. 975 Ellicott Square," will be cared for, and information gladly furnished regarding the Exposition and other points of interest to engineers in the city and vicinity.

A stenographer will be in attendance, whose services may be procured by visiting engineers.

Meetings of the Society are held the first Tuesday in each month, at which all visiting engineers will be most heartily welcomed.

Yours respectfully,
WILLIAM A. HAVEN,
Prest. Engrs.' Soc. W. N. Y.

The Executive Board reported the election of the following gentlemen: As members, Stanley W. Hayes and Edward Denison Hooker; as associates, Leslie J. Bennett and Warren Rodney.

It was moved by Mr. Knighton and seconded by Mr. Norton that a special invitation be sent to the new members, and some little extra exertion made to become acquainted with and to entertain them. Carried.

Mr. Neher read a paper on concrete construction.

Mr. Neher's paper was discussed by Messrs. Diehl, Haven, Knighton, Vander Hoek, Tutton, Rockwood and Norton, and the author.

Meeting adjourned at 10.30 P.M.

G. C. DIEHL, *Secretary.*

Engineers' Club of Minneapolis.

141ST MEETING, FEBRUARY 18, 1901.—The meeting was held in connection with a dinner at the Commercial Club.

The Club listened to reports and addresses by the outgoing officers: Geo. W. Sublette, President; W. W. Redfield, Librarian; H. E. Smith, Secretary-Treasurer; Geo. D. Shepardson, member Board of Managers of

Association of Engineering Societies. Also addresses by incoming officers: W. W. Redfield, President; C. L. Pillsbury, Vice-President; J. E. Carroll, Librarian; Edward P. Burch, Secretary-Treasurer; Wm. R. Hoag, member Board of Managers of Association of Engineering Societies.

Col. J. T. Fanning, who was present as a guest of the Society, gave an interesting address on "Engineering in the Last Century." Past Vice-President Irving E. Howe and others also spoke informally.

Mr. Fanning was unanimously elected an honorary member of the Club.

142D MEETING, MARCH 18, 1901.—The meeting was held in connection with a dinner at the Guaranty Restaurant.

The following new members were unanimously elected: Messrs. C. H. Chalmers, Edwin R. Williams, P. P. Crafts, James Gillman, F. B. Slocum. The following names were proposed for membership: Frank H. Nutter, Wm. Robertson, Frank E. Reidhead.

Mr. W. S. Pardee presented a lecture on "Methods in Scientific Study," which proved to be of great interest to the Society.

Bills before the Legislature for State Aid for Good Roads and for Licensing of Bicycles were called to the attention of the Club by the President. A committee was appointed to act with a committee from the Civil Engineers' Society of St. Paul, and to take such action as seemed necessary to push certain worthy bills through the Legislature. Prof. Wm. R. Hoag, Geo. W. Sublette and W. S. Pardee are on this committee.

EDWARD P. BURCH, *Secretary*.

Association of Engineering Societies.

Vol. XXVI. APRIL, 1901. No. 4.

PROCEEDINGS.

Engineers' Society of Western New York.

Regular Meeting, April 2, 1901.—The meeting was called to order at 8.30 p.m., the President in the chair. The following members present: Messrs. Haven, Tutton, Buttolph, Knapp, Vander Hoek, Booz, Boardman, Hooker, Ricker, Babcock. March, Fruaff, Knighton, Diehl, Norton, Rogers, Bardol, Weston and Caines. Visitor, Mr. Holmes, of the Engineers' Society of Western Pennsylvania.

It was voted that the minutes of the last regular meeting be approved as printed.

Mr.Tutton, member of the Board of Managers, made a report.

Application for membership was received from Mr. James Leland Averill, and it was voted that the same be accepted and submitted to letter ballot.

The Secretary reported that the Society had elected as Associates, Messrs. John Feist and William Franklin.

The President said that there seemed to have been some misunderstanding how to vote on the new form of ballot which was used for the first time in January. It was unanimously voted by the Society to temporarily suspend so much of the By-laws as relates to the reapplications of persons not elected on letter ballots canvassed January 2, 1901, and that the Secretary be instructed to send out letter ballots for Horace P. Chamberlain and Eugene C. Hanavan.

Mr. March, the Committee appointed on the matter of the Society joining the International Association for Testing Materials, made a report, which was briefly discussed by Messrs. Ricker, Tutton, Knighton and Diehl. It was then voted to accept the report and discharge the Committee. It was also voted that the subject matter be left to the discretion of the Librarian, with power.

The President reported that the Secretary had sent out a large number of the "Pan-American Circulars" to engineering societies in North and South America, and to some parts of Europe. The Secretary read several letters which had been received in response thereto, all of which

thanked the Society for their courtesy, and said they would avail themselves thereof.

The President then said it would be necessary to have a large Committee on Reception of Visiting Engineers. Thereupon it was unanimously voted that the President should appoint a Committee of seventeen or more members as a Reception Committee.

The President appointed the following as such Committee:

George A. Ricker, Past President; Wallace C. Johnson, Past President; Thomas W. Symons, Honorary Member; Harry B. Alverson, F. V. E. Bardol, George B. Bassett, W. A. Brackenridge, Newcomb Carlton, David A. Decrow, Samuel J. Fields, William Franklin, E. F. Gaskin, Marvine Gorham, Edward B. Guthrie, Richard Hammond, William C. Houck, S. M. Kielland, Clarence C. Lewis, Harry J. March, Dr. Truman J. Martin, Charles M. Morse, Charles Mosier, Maurice B. Patch, J. Vander Hoek, J. F Witmer, and all the members of the Executive Board without special appointment.

Discussion was then had upon Mr. Ricker's paper on "Docks."

The President welcomed Mr. Holmes, of the Engineering Society of Western Pennsylvania, who replied: In coming to the meeting of the Society to-night I did not expect to be called upon to make a speech. I appreciate the honor of being invited, and congratulate you on the manner in which I have been received. If you treat every visitor the same as you have treated me, they will surely come again. I have the honor of belonging to the Western Pennsylvania Society of Engineers and we have four hundred members in Pittsburg. We have a house, the first floor of which is rented. We have our rooms on the second and third floors, which contain the reception room, a library, a large hall for meetings and other rooms. We would like to have a better house, and are trying to get it. We have meetings every month, and in summer have a trip by boat, and in the winter a banquet. We had a banquet in February last, at which time we probably had 300 or 400 members with their friends. Our membership is made of engineers from the Carnegie, Jones & Laughlin, the Westinghouse interests and manufactories in the city. We number among our members such men as William Metcalfe, Thomas F. Johnson, of the Pennsylvania lines, etc. Our former Secretary was Reginald D. Fessenden, who had charge of the Wireless Telegraphy experiments for the Government.

I notice on your walls a number of photographs of Pittsburg. Among them the skeleton of the Carnegie Building. Mr. Frick is building an office building of about the same size. Back of this building is the Fifth Avenue Hill. We hope in time to have this hump cut down, when they will have two additional stories. On the lot there used to stand an old stone church, built a great many years ago. The church was taken down, each stone marked and put up in the same manner as in the original building.

If any of the members of this Society come to Pittsburg we would be glad to have you make use of our rooms.

The President.—What is the population of Pittsburg?

Mr. Holmes.—Pittsburg and Allegheny, 400,000. We should take in more territory. We should take in McKeesport, Braddock, Wilkens and East Pittsburg, when the population would be very much larger. Allegheny, just across the river, should be in Pittsburg.

THE PRESIDENT.—How long has the Society been organized?

MR. HOLMES.—About twenty-one years at the last annual meeting, I think.

THE PRESIDENT.—You say you have 400 or 500 members?

MR. HOLMES.—I am not sure of the exact number, but I think it is between these figures.

MR. NORTON.—I think at the January meeting, the President incidentally said that we have no quicksand in Buffalo. Test borings were taken by Mr. Caines for the purpose of finding out the soil to be encountered in building the abutments for a bridge on South Michigan street. We found what could be called quicksand. This sand I dried out and have tried it on a No. 50 sieve, and there was no perceptible amount retained. On a No. 100 sieve there was ½ of 1 per cent. retained and on a No. 200 sieve there was only about 25 per cent. retained, making that sand, on a sieve test, finer than the tests for Portland cement. It was a pure quartz sand if that would be called quicksand. Is quicksand composed simply of quartz?

MR. TUTTON.—A great deal of information on this subject is contained in a discussion which took place before the American Society on Mr. Landreth's paper on the Erie Canal, and there was a great variety of opinion—one member claiming there was no quicksand unless it possessed that peculiar property of "quaking," etc. The decision arrived at was that quicksand was pure quartz sand in which the particles were worn round, the actual fineness of the sand had nothing to do with it. I am not sure that I am quoting these conclusions right, and would refer you to that paper, giving the best information on quicksand outside of McAlpine's writings on it.

Boston Society of Civil Engineers.

BOSTON, MASS., APRIL 17, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 P.M.; President Lawson B. Bidwell in the chair. Fifty-five members and visitors present.

The record of the annual meeting of March 20, 1901, was read and approved.

Messrs. Charles M. Spofford, Herbert R. Stearns and Frank W. Upham were elected members of the Society.

The Secretary reported for the Board of Government that it had voted to continue the same special committees of the Society as last year, and that the membership thereof had been selected as follows:

Committee on Quarters—Desmond FitzGerald, E. W. Howe, C. Frank Allen, E. W. Bowditch and H. Bissell.

Committee on the Library—L. F. Cutter, F. P. McKibben, F. H. Fay, A. D. Flinn and H. F. Bryant.

Committee on Excursions—J. R. Burke, Theodore Horton, J. Albert Holmes, H. K. Higgins and H. D. Woods.

Members of the Board of Government, Association of Engineering Societies—S. E. Tinkham, J. R. Freeman, Henry Manley, Fred. Brooks and Dexter Brackett.

A committee, consisting of L. F. Rice, Desmond FitzGerald and Henry Manley, was also appointed to petition the General Court for authority to hold real and personal estate in excess of $20,000.

A communication was read from the Engineers' Society of Western New York, extending a cordial invitation to the members of this Society to make use of the rooms of the Engineers' Society of Western New York during the Pan-American Exposition. The Secretary was directed to acknowledge the receipt of the invitation and to express the appreciation of the Society.

Mr. W. W. Cummings read the paper of the evening entitled, "Subaqueous Tunnels for Gas Conduits." The paper was illustrated by stereopticon views. In the discussion which followed, Mr. Carson spoke briefly of the tunnels built for the Metropolitan Sewerage Works, and of the work which had been accomplished on the East Boston Tunnel, and Mr. Saville of the tunnel recently completed for the Metropolitan Water Board under Mystic River at Chelsea North Bridge.

Mr. Robert A. Shailer, President of the Boston Tunnel Construction Company, the contractors for the East Boston tunnel, gave some interesting experiences of the use of compressed air in tunnel work, speaking particularly of the work at Cleveland, Ohio.

Adjourned. S. E. TINKHAM, *Secretary.*

Engineers' Club of Minneapolis.

THE 143d regular meeting of the Club was held at 8 P.M., on April 15, at its permanent quarters in the County Commissioner's rooms in the County Court House.

Thirteen members and eight visitors present.

After the usual order of business was disposed of, a paper was presented by Col. J. T. Fanning, entitled "Canals and Canal Devices."

A second paper was presented by Mr. E. H. Tromanhauser, on "Grain Elevator Construction."

These papers were of great interest to the members. The first was historical in nature; the second was on up-to-date steel elevator design construction,—a subject of great local interest.

The discussion of the papers was deferred one month.

EDWARD P. BURCH, *Secretary.*

Engineers' Club of Cincinnati.

122D REGULAR MEETING, CINCINNATI, OHIO, MARCH 21, 1901.—Dinner was served at 6.15 P.M.

The regular meeting was called to order at 8 P.M., Mr. A. O. Elzner in the chair, and fifteen members present.

Minutes of the meeting of February 21 were read and approved.

On ballot being taken, Mr. Alex. H. Miller was elected an Active Member.

The following question was presented:—

What kind of explosives do you prefer for blasting in the following kinds of material?

Solid rock, quarried for building.

Solid rock, for removing only.

Loose rock and shale.

Hard pan and cemented gravel.

Loose sand and gravel.

On motion, the same was ordered announced for discussion at the next meeting.

Mr. E. E. Russell Tratman, Resident Editor *Engineering News,* at Chicago, who was visiting the city in the interest of his paper, and who had been invited to attend the meeting, favored the Club with a few remarks, principally on the subject of water works, as he had visited during the day the work being done at California for the new plant for the Cincinnati water supply.

The paper for the evening was read by Mr. M. D. Burke, on "Inland Transportation in the Mississippi Valley."

J. F. Wilson, *Secretary.*

Engineers' Club of St. Louis.

524th Meeting, April 3, 1901.—Held at 1600 Locust street, at 8.20 p.m., Vice-President Kinealy presiding.

The minutes of the 523d meeting were read and approved.

Motion was made and carried to reconsider the action of the Club at the last meeting, in which it was decided that the Executive Committee be directed to pay the $100 assessed against the Engineers' Club by the Public Welfare Commission, same to be paid out of the Entertainment Fund. After considerable discussion of the matter, it was finally decided, upon motion being carried, to lay the matter on the table.

The application for membership of Mr. Rudolph Howard Klauder was read.

The subject of the evening was a paper by Mr. Louis Bendit, entitled "Treatment of Feed Water for Boilers." Mr. Bendit paid particular attention to the various methods of treating hard waters for use in boilers, and presented considerable data upon the same.

Discussion was participated in by Messrs. Wheeler, Bryan, Freeman and Professor Keiser, Professor of Chemistry at Washington University.

Adjourned to Library room, where lunch was served.

W. G. Brenneke, *Secretary.*

525th Meeting, April 17, 1901.—Held at 1600 Locust street, at 8.20 p.m., President Spencer presiding.

Twenty-five members and five visitors were present.

The minutes of the 524th meeting were read and approved, the doings of the 308th meeting of the Executive Committee were reported.

Mr. Rudolph Howard Klauder was duly elected to membership.

The matter of the assessment of $100 against the Club by the Public Welfare Commission then came up.

Moved by Professor Van Ornum and seconded by Mr. Flad, "that the matter be referred to the Executive Committee with power to act."

Mr. Wheeler spoke against the motion and advocated delaying action until a better representation of members could be secured.

Mr. Reber spoke in favor of definite action at once, and was in favor of making the appropriation.

Mr. Flad then withdrew his second to Professor Van Ornum's motion.

Mr. Reber then moved "that the St. Louis Engineers' Club contribute $100 to the Public Welfare Commission."

Mr. Flad seconded the motion.

President Spencer, the Club's representative on the Public Welfare Commission, then spoke on the subject. He explained that Professor Chaplin, when President, had appointed him as the club's representative on the Commission, and how other representatives were appointed. He also said it was thought at that time that the various members of the Commission would need do nothing more than contribute their labor in behalf of the Commission. In the meantime, it has been found that considerable expense has accrued, and it is necessary to meet the same. At the same time, he explained, the Club was not bound in any way to pay the assessment made, but that he knew that three of the organizations appealed to had contributed, and most of the others had probably done so.

Mr. Reber then withdrew his motion.

Professor Van Ornum then moved "the Club ask for the money, the same to be paid in such manner as the Executive Committee may decide."

Seconded by Mr. Bryan.

Amended by Mr. Flad "to refer the whole matter to the Executive Committee."

The following letter was then read by the Secretary:

St. Joseph, Mo., April 15.

Mr. W. G. Brenneke, Secretary Engineers' Club, Fullerton Building, St. Louis, Mo.

Dear Sir: I have your notice of the 13th, with regard to the next meeting of the Club, to be held on Wednesday evening, and regret exceedingly that I will not be able to be present to record my vote against the diversion of any portion of the entertainment fund as a subscription to aid the Public Welfare Commission in their work.

As I have not been present at any of the recent meetings of the Club, I don't know anything about the Public Welfare Commission, nor its purposes; they may be the best in the world, and it may be that it might be well for the Club to subscribe to help out the work, though I am inclined to think that the Executive Committee's recommendation that the objects of the Club did not warrant their making an appropriation of this character, is the correct view to take of the case, especially if the Commission is, as I suppose, of a political character; of this, however, I am not certain.

So far as the entertainment fund is concerned, this was set apart by the Club when I was an active member, and I think when I was a member of the Executive Committee, for a definite purpose; and my recollection is that the bulk of the fund as it is now constituted, was a special gift to the Club for the purpose of entertainment of distinguished engineers visiting the city, and the Club certainly has no right to divert this gift to any other use.

I will be very much obliged, if the matter comes up at the next meeting and is discussed, if you will read my letter, or have it read, as a part of the discussion, and as expressing the views of one of the Past Presidents of the Club. Yours truly, Ben. L. Crosby.

Amendment seconded and carried.

The subject of the evening was, "Some Notes on Roofs and Roofing Materials."

Mr. Wheeler divided roofing into four great classes,—viz., Felts, Woods, Metals and Silicates. The felts were divided into tarred felts, gravel, ready rock and ruberoid. The woods were divided into boards, slabs and shingles. The metals into corrugated iron, tin, lead and copper. The silicates were divided into mud, slate and tiles.

The advantages and disadvantages of each kind, when laid in flat or pitch roofs or both, together with costs and weights per square, and durability, were discussed. The costs given did not include that of supporting material.

There were also presented a number of samples of shingle and interlocking tiles, and a number of illustrations showing tile roofs.

The Chair announced his resignation, for business reasons, as a member of the Committee on Filtration, and also announced the appointment of Professor W. S. Chaplin as his successor.

Adjourned to Library room, where lunch was served.

W. G. Brenneke, *Secretary.*

Association of Engineering Societies.

Vol. XXVI. | May, 1901. | No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

526th Meeting, May 1, 1901.—Held at 1600 Locust street, at 8.20 p.m.; Vice-President Kinealy presiding.

Twenty members and five visitors present.

The minutes of the 525th meeting were read and approved, the minutes of the 309th meeting of the Executive Committee were reported.

The application of Mr. Ernest C. F. Koken was read and referred to the Executive Committee.

The subject of the evening was an account by Mr. Flad of his recent trip to Europe, illustrated by lantern slides of kodak snap shots taken by him during the trip. Among the views shown were many of the different filtration plants which he visited, some of these plants being in successful operation and some in process of construction, all of which were described in more or less detail.

The following Committee on Prizes was announced: B. H. Colby, chairman; J. A. Ockerson, Carl Gayler, W. A. Layman, E. R. Fish.

The Chair announced as the subject of the next meeting a paper by Mr. Duncan F. Cameron on "Coal Supply of St. Louis and Adjacent Territory."

Adjourned to Library room, where refreshments were served.

E. B. Fay, *Secretary pro tem.*

527th Meeting, May 15, 1901.—Held at 1600 Locust street; President Spencer presiding.

Present, twenty-six members and six visitors.

The minutes of the 526th meeting were read and approved. The minutes of the 310th meeting of the Executive Committee were reported.

The applications for membership of Messrs. Hans Carl Toensfeldt and Arthur Tappan North were read.

Mr. Ernest C. F. Koken was elected to membership.

There being no miscellaneous business, attention was paid to the paper of the evening, entitled "The Coal Supply of St. Louis and Adjacent Territory," by Mr. Duncan F. Cameron, superintendent of mines for Donk Bros. Coal and Coke Co.

Mr. Cameron took up in a general way the extent of coal territory tributary to St. Louis, giving areas of these coal measures, also their total annual production and the consumption of bituminous coal by the city of St. Louis.

He then discussed in detail what had been done in the way of washing coal at the mines, the result of which is the elimination of the slate and iron pyrites. The construction of a modern coal-washing plant was explained, the same being illustrated on the screen. Mr. Cameron stated tests have been made in office building steam plants in St. Louis and at other places showing a saving of 20 per cent. to 28 per cent. of fuel bills by using washed coal instead of unwashed coal.

It was also stated that a very fair quality of coke had been made from washed Illinois coal in ovens which were not altogether of modern type.

Experiments, the object of which are to produce a good foundry coke from Illinois coal, are being continued with considerable promise of success.

The discussion was participated in by Messrs. Bryan, Kinealy, Blaisdell, Philip Moore and others.

Adjourned to Library room, where light refreshments were served.

W. G. Brenneke, *Secretary.*

Engineers' Club of Cincinnati.

123D Regular Meeting, Cincinnati, Ohio, April 18, 1901.—Dinner was served at 6.20 p.m.

The regular meeting was called to order at 7.30 p.m., with President Jewett in the chair and thirteen members present.

Minutes of the meeting of March 21 were read and approved.

The question, presented at the last meeting for discussion, was taken up and discussed by Messrs. Lilly, Nicholson, Jewett and others, giving their experience and practice in the use of explosives for blasting for the removal of different materials.

The following question was presented: What can be done to increase the usefulness of the Cincinnati Engineers' Club? This was considered very apropos and the Secretary was directed to announce it for discussion at the next meeting.

Mr. Ward Baldwin read the paper for the evening, mostly extempore, on the subject, "Present Practice in Specific Loading for Railroad Bridges," being a comparison and discussion of the loads called for by the specifications of a large number of prominent railroads at the present time and of the great increase in most of them over what was specific in the year 1894, when he made a similar examination and comparison.

The subject was discussed by Messrs. Nicholson, Wulff, Read, Lilly, Bogen, Jewett and others.

After a vote of thanks to Mr. Baldwin for his paper, the meeting adjourned.

J. F. Wilson, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, San Francisco, May 3, 1901.—Called to order at 8.30 p.m. by President Marx. The minutes of the last regular meeting were read and approved.

Mr. A. S. Riffle, a civil engineer, was elected to membership upon a regular count of ballots.

A posthumous paper by the late President, Geo. W. Percy, entitled "Reflections of Vitruvius," was read by Mr. G. A. Wright.

Adjourned.

Otto von Geldern, *Secretary.*

Boston Society of Civil Engineers.

Boston, Mass., May 15, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President Lawson B. Bidwell in the chair. Total number present, members and guests, including ladies, one hundred and nineteen.

The record of the last meeting was read and approved.

The Secretary read a communication from the Secretary of the International Engineering Congress, to be held in Glasgow, in September next, inviting this Society to select a delegate to attend the congress as an honorary member.

On motion of Mr. Henry Manley, the communication was referred to the Board of Government with authority to select a delegate if the board deems it expedient.

On motion of Mr. Holmes, the thanks of the Society were voted to Mr. Thomas W. Lawson for courtesies extended on the occasion of the visit to his new yacht "Independence" at the Atlantic Works, East Boston; also to the Boston Transit Commission and to Mr. Robert A. Shailer, President of the Boston Tunnel Construction Company, for courtesies extended at visit to the works of the East Boston Tunnel on May 4, 1901.

On motion of Mr. Higgins, the thanks of the Society were voted to the Boston Elevated Railway Co. for courtesies extended this afternoon on the occasion of the trip over the elevated lines of that company in Charlestown and to its terminal station at Dudley street, Roxbury.

Mr. Frank W. Skinner, of the *Engineering Record,* was then introduced and gave a very interesting lecture, entitled "Some Difficult and Curious Foundations." The lecture was profusely illustrated by lantern slides.

On motion of Professor Swain, the thanks of the Society were voted to Mr. Skinner for his entertaining and instructive lecture.

Adjourned.

S. E. Tinkham, *Secretary.*

LISTS OF MEMBERS

OF THE SOCIETIES COMPOSING THE

Association of Engineering Societies.

DECEMBER 31, 1900.

Lists of Members of the Associated Societies.

Abbreviations for designating membership:

For Honorary Member.......................Hon. Mem.
For Member.................................Mem.
For Associate Member......................Assoc. Mem.
For Junior Member.........................Jun. Mem.

Boston Society of Civil Engineers.

Adams, Edward P., Mem.,
Landscape Architect and Civil Engineer,
53 State street, Room 1104, Boston, Mass.

Adams, Henry S., Mem.,
Civil Engineer, 53 State street, Room 542, Boston, Mass.

Addicks, Walter R., Mem.,
Chief Engineer, Boston, Bay State and other local gas companies,
24 West street, Boston, Mass.

Aiken, Charles W., Mem.,
Consulting and Contracting Engineer,
82 Washington street, New York, N. Y.

Aiken, Roy C., Mem.,
Civil Engineer, 1059 Washington street, Boston, Mass.

Allard, Thomas T., Mem.,
Civil Engineer, Fort Caswell, N. C.

Allen, C. Frank, Mem.,
Professor of Railroad Engineering, Mass. Inst. of Technology,
Boston, Mass.

Allen, Charles A., Mem.,
Consulting Engineer, 44 Front street, Worcester, Mass.

Andrews, David H., Mem.,
Proprietor Boston Bridge Works, 70 Kilby street, Boston, Mass.

Appleton, Thomas, Mem.,
Civil Engineer, United States Life Saving Service,
17 State street, New York, N. Y.

Armstrong, Samuel G., Mem.,
Civil Engineer,
Amalinda, Upper Buitenkant street, Cape Town, South Africa.

Aspinwall, Thomas, Mem.,
Aspinwall & Lincoln, Civil Engineers,
120 Tremont street, Room 606, Boston, Mass.

Atwood, Joshua, 3d, Mem.,
Civil Engineer, 158 Foster street, Brighton, Boston, Mass.

Atwood, Thomas C., Mem.,
Civil Engineer, 362 Cross street, Malden, Mass.

Badger, Frank S., Mem.,
Assistant Engineer, Continental Filter Co.,
35 Wall street, Room 24, New York, N. Y.

Bailey, Ernest W., Mem.,
City Engineer, City Hall, Somerville, Mass.

Bailey, Frank S., Mem.,
Assistant in Engineering Department, Massachusetts State Board of Health, 140 State House, Boston, Mass.

Bailey, William M., Mem.,
Engineer, Eastern Expanded Metal Co.,
20 Pemberton Square, Boston, Mass.

Baker, William E., Mem.,
General Superintendent Manhattan Ry. Co.,
10 Dey street, New York, N. Y.

Baldwin, Loammi F., Mem.,
Civil Engineer, 31 Milk street, Boston, Mass.

Bancroft, Lewis M., Mem.,
Superintendent of Water Works, Reading, Mass.

Barbour, Frank A., Mem.,
Snow & Barbour, Civil and Sanitary Engineers,
1120 Tremont Bldg., Boston, Mass.

Barnes, Rowland H., Mem.,
Pierce & Barnes, Civil Engineers, 7 Water street, Boston, Mass.

Barnes, T. Howard, Mem.,
Civil and Municipal Engineer, 7 Water street, Boston, Mass.

Barnes, William T., Mem.,
Resident Engineer, Baltimore and Ohio Southwestern Ry.,
Washington, Ind.

Barrows, Harold K., Mem.,
With Metropolitan Water Board, 1 Ashburton Place, Boston, Mass.

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